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RADIATION LABORATORY

Report M-210 April 10, 1946

HANDBOOK OF MAINTENANCE INSTRUCTIONS FOR A REPLACEMENT PRESSURIZED R-F UNIT TO BE USED WTH MODEL AN/APS-15A AIRCRAFT RADAR EQUIPMENT

ABSTRACT

This manual provides installation, operating, and maintenance instructions for a Replacement Pressurized R-F Unit to be used with AN/APS-15A equipments. This manual is intended to serve as a supplement to the "Handbook of Maintenance Instructions for Model AN/APS-15A and AN/APS-15B Aircraft Radar Equipment." It is supposed that the two books will be used together; therefore, repetition has been avoided.

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REPLACEMENT PRESSURIZED R-F UNIT FOR AN/APS-15A

I. GENERAL DESCRIPTION.

1. *Introduction.*

The purpose of this manual is to provide installation, operating, and maintenance instructions for a Replacement Pressurized R-F Unit to be used with AN/APS-15A equipments. This manual is intended to serve as a supplement to the "Handbook of Maintenance Instructions for Models AN/APS-15A and AN/APS-15R Aircraft Radar Equipment." It is supposed that the two books will be used together; therefore, repetition has been avoided. Rather than include numerous references and footnotes, this report will rely on similarity of text and numbering procedure for cross reference purposes.

2. *Purpose of Equipment.*

The Replacement Pressurized R-F Unit for AN/APS-15A is suitable for field modification of existing AN/APS-15A equipment. This unit is also suitable for modification of AN/APS-15 equipment, but the installation is slightly more difficult. It was designed primarily to improve the beacon reception facilities of the AN/APS-15A, but should also result in more dependable radar operation and reduced maintenance difficulties. An improvement of more than 15 decibels in beacon sensitivity and automatic frequency control for beacon reception have been provided. Also, improvements have been made in the signal AFC circuits and in the r-f components.

With the Pressurized R-F Unit, the AN/APS-15 modulator is mounted in an upright position. This change should result in a greatly increased life for the 715R modulator tube, which, when operated inverted by the Eighth Air Force, had an average life of less than 50 hours.

3. *Description of Components.*

a. *General Description.*

This kit contains all parts required for conversion of an AN/APS-15A installed in a B-17 or B-24 aircraft. It consists of the following parts:

(1) Pressurized R-F Unit, which includes:

(a) Duplexer with broad-band ATR tube;

(b) Solenoid operated TR tuning plunger for beacon reception;

(c) Double mixer, providing separate crystals for receiver, radar AFC, and beacon AFC;

(d) Automatic frequency control circuits for both radar and beacon reception;

(e) Wide-band, three-stage preamplifier with grid-bias gain control;

(f) Keep-alive supply for the TR tube.

(2) Auxiliary Power Supply, to be mounted inside the R78/APS-15A Receiver-Indicator.

(3) Mounting frame for R-F Unit, Modulator, and Antenna Assembly.

(4) Mounting bracket for J15B/APS-15 Junction Box.

(5) Interconnecting R-F Lines, including directional coupler.

(6) Extensions for cables I, J, and S.

(7) Vibration mounts.

(8) Miscellaneous hardware—nuts, bolts, etc.

The mounting brackets and cable extensions are designed for installation in B-17 aircraft but are also applicable for installation in B-24 or PB4Y1 aircraft. Figure 6-1 shows a mockup of the Replacement Pressurized R-F Unit installation for B-17 aircraft.

b. *Size and Weight of Components.*

The size and weight of the components are tabulated below. Some of these replace parts in the original installation. (See paragraph c below.)

Component	*Weight (lbs.)*
Pressurized R-F Unit	25.2
Auxiliary Power Supply	6.9
Mounting Base	11.0
Antenna Support Rods (4)	2.6
R-F Lines	
Transmitter Line, Z1	1.0
Input Line, Z2	.7
Output Line, Z3	1.3
Alignment Section, Z4	.3
Flexible Line, 5	1.2
Bracket for Junction Box	.6
Cables	
RR	
I-1	1.9
J-1	
S-1	
Vibration mounts (6)	1.9

Maximum Dimensions (In.)

W	L	H
11½	11½	13-7/8
4½	11-13/16	9-3/16
18½	29-3/8	7-3/8
1½ dia.	7-7/8	

c. *Weight of Parts Removed from Standard B-17 Installation.* The first two items below are part of the original AN/APS-15A equipment. The others are installation parts supplied by the Army modification center.

Component	Weight (lbs.)
Duplexer and Preamplifier Assembly	8.1
R-F Line Assembly	2.3
Modulator Mounting Back	10.3
Shockmount Assemblies (4)	4.9
Bracket for Junction Box	.6

d. *Net Weight Added to B-17 Installation by Modification Kit.*

Total weight of equipment added	54.6 lbs.
Total weight of equipment removed	26.2 lbs.
Net weight added	28.4 lbs.

4. *List of Vacuum Tubes Used.*

All vacuum tubes, crystals, and rectifiers used in the Replacement Pressurized R-F Unit are listed below:

a. *Pressurized R-F Unit.*

Tube	Type	Number Used
1B24	TR Tube	1
1B35	ATR Tubes	1
1N23-A or B	Crystal	3
2D21	Gas Tetrode	2
2K25-723A/B	Klystron	2
6AK5	Pentode	8
23D1071	Selenium Rectifier	1
1Q23	Beacon Reference Cavity	1

b. *Auxiliary Power Supply.*

Tubes	Type	Number Used
5U4G	Rectifier	1
VR105-30	Voltage Regulator	1
VR150-30	Voltage Regulator	1

II. INSTALLATION.

1. *General Installation Information.*

a. *Cabling Changes.*

Figure 8-1 shows the electrical connections (exclusive of R-F lines) to the R-F Unit. These connections are made through cables K, AX, and BB. Cable BB is a new cable for AN/APS-15A, but the J15B/APS-15 junction box has a connector for this cable which is used with AN/APS-15B equipments. Extensions for cables I, J, and S are provided.

b. *Mechanical Changes.*

The BT-15A/APS-15 Transmitter-Converter, the AS-18A/APS Antenna Unit are remounted with the Pressurized R-F Unit, using the Mounting Base supplied for that purpose. Existing holes in the plywood mounting plate may be used except that small holes for securing the vibration mounts and the mounting bracket for the J15B/APS-15 Junction Box must be drilled as shown in Figure 6-5. The Auxiliary Power Supply is readily mounted above transformer T-201 in the R78/APS-15A Receiver-Indicator using existing holes, as shown in Figure 6-2.

2. *Detailed Installation Instructions.*

a. *Changes to Receiver-Indicator R78/APS-15A.*

(1) Remove receiver strip and its mounting tray.

(2) Remove connector J203 (cable C on Receiver-Indicator) from front panel to facilitate soldering new leads to pins J, K, and L.

(3) Install the auxiliary power supply over transformer T-201, as shown in Figure 6-2. Use existing screws and holes.

(4) Push the power supply cable leads through the chassis hole used for the leads to the A-scope socket, and route the two long leads (105v and 150v) along the large cable toward the rear of the indicator chassis, across the chassis, and to the front corner, near J203. These leads should be pushed under the cable clamps and laced to the large cable.

(5) Solder the ground (black) lead to the grounding lug on tube socket X-218.

(6) Solder the 115v ac (white) leads to pins 1 and 2 of T-201.

(7) Solder the 115v (orange) lead to pin L of J203.

(8) Remove the lead from pin A of J204 (connector for cable A). Tape the end of this wire to prevent it from making contact with other circuits or ground. Connect the 105v (blue) lead from the auxiliary power supply to pin A of J204.

(9) Remove the lead connecting the Beacon-Search switch, S204, to the Manual-AFC switch, S209. Solder a new lead, 11 inches long, to the same terminal of S209.

(10) Solder the other end of the new lead of 9, above, to pin K of J203.

(11) Remove the Receiver Gain Control potentiometer, R289, from the front panel. Do not disconnect the leads. Add a new lead, 11 inches long, to the center terminal and fasten the potentiometer back into the panel.

(12) Solder the other end of the new lead in 11, above, to pin J of J203.

(13) Fasten J203 back onto the front panel. Be sure to put the grounding lead under one of the four mounting screws.

(14) Replace the receiver mounting tray.

(15) Replace R281 with a 2,000 ohm, 24 watt resistor.

(16) Add a 40K ohm, 3 watt resistor from 300v to ground (pin 8 of V221 to ground lug).

(17) Remove the wire from pin 1 of J704 (—255v) of the receiver strip and tape the end. Use

the lead between the innermost contact of relay K701 and R741 (2.2 megohms) to connect the innermost contact of relay K701 to pin 1 of J704.

(18) Remove tubes V709, V710, V711, V712, and V713, and cover these sockets with masking tape.

Mark the receiver strip "Modified for use with Pressurized R-F Unit", and reinstall it in the Indicator.

b. *Changes to Junction Box, J15B/APS-15.*

(1) Remove back cover of Junction Box.

(2) Remove high voltage warning plate from the cover and drill out the rivets which hold the Allen (hex) wrench clips.

(3) Place the Junction Box cover and the J. B. mounting bracket, which is a part of the R-F Unit kit, together so that holes can be drilled through both cover and bracket. The holes may be drilled so that the mounting holes can be used to remount the high voltage warning plate and Allen wrench clips on the back of the mounting bracket.

(4) Remove connector C from the Junction Box and open the lacing near the connector.

(5) Connect pin F of connector BB to pin K of connector C.

(6) Connect pin G of connector BB to pin J of connector C.

(7) Remove lead O of cable K from the secondary (terminal 3) of filament transformer T-1201 and connect it to pin L of connector C.

(8) Fasten the mounting bracket and Junction Box cover to the plywood mounting plate in the airplane and fasten the Junction Box to its cover.

c. *Changes to Transmitter-Converter RT-15A/APS-15.*

(1) Remove the RT-15A/APS-15 Transmitter-Converter from the airplane.

(2) Remove the preamplifier and duplexer assembly from the bottom of the modulator.

(3) Remove condenser C117 and its mounting bracket. Cut off the TR keep-alive voltage lead and tape it to prevent accidental grounding.

(4) Fasten the adjustable mounting bracket in place as shown in Figure 6-3.

(5) Fasten the transmitter r-f line to the magnetron and then tighten the clamping nuts of the adjustable mounting bracket so that no strain is applied to the magnetron.

(6) Cut a notch in the bottom cover of the Transmitter-Converter to clear the new r-f line. Fasten the cover in place.

(7) Fasten the four angle brackets used for packing the RT-15A/APS-15A Transmitter-Converter for shipment in place.

d. *Assembly.*

The relative location of the units when assembled is shown in Figure 6-4.

(1) Removal of existing parts:

(a) Remove the r-f lines which interconnect the Transmitter-Converter and Antenna, and disconnect all cables.

(b) Remove the Transmitter-Converter, Junction Box, and mounting frame by removing the four nuts which fasten the frame to the shockmounts.

(c) Remove the four shockmount assemblies one at a time, replacing each one with one of the Antenna Support Rods.

(d) Remove the rectangular, plywood cover-plate and alter it as required to clear the vibration mounts when installed as described below.

(2) *Installation of new parts.*

(a) Drill mounting holes in the plywood mounting plate as shown in Figure 6-5.

(b) Fasten the vibration mounts in place.

(c) Assemble the Transmitter-Converter, Pressurized R-F Unit, R-F lines, and Mounting Base as shown in Figure 6-4. Note—Be sure to install rubber gaskets at all waveguide connections.

(d) Fasten the assembly of (c), above, in place and attach the four antenna support rods to the Mounting Frame.

(e) Carefully bend the flexible r-f line to form a 90° bend and fasten it in place.

(f) Connect the pressurized hose from the MK-23/AP Pressurizing Unit to the fitting on the output r-f line.

e. *Cables.*

(1) Connect cables f, J, and S from the J15B/APS-15 Junction Box to the RT-15A/APS-15 Transmitter-Converter using the extension cables provided.

(2) Connect cables K, AX, and BB from the J15B/APS-15 Junction Box to the Pressurized R-F Unit.

(3) Cable C, from the R78/APS-15 Receiver-Indicator to the J15B/APS-15 Junction Box, must have pins J, K, and L connected. These wires may not be present and may have to be added. Size No. 18 AWG wire is satisfactory.

3. *Alternate Installation.*

The Antenna Unit may be mounted solidly to the airplane and connected to the Pressurized R-F Unit by means of flexible waveguide. In this case the Mounting Frame for the Modulator and R-F Unit should be supported by vibration mounts at the four corners; omitting the antenna support rods and the two middle vibration mounts.

4. *Adjustments.*

a. *Pressurizing.*

The Pressurized R-F Unit and r-f lines are pressurized together. Use of flexible waveguide between the Antenna Unit and the R-F Unit should eliminate strains on the waveguide joints and the resulting air leaks. A pressure pump with dehydrator and automatic absolute pressure control such as the MK-23/AP or HD-17/AP should be connected to the fitting on the output r-f line. The advantage of pressurizing the local oscillator tubes is, of course, dependent upon the proper functioning of the pressurizing unit, which should be adjusted to provide a slight positive pressure on the ground (1 or 2 p. s. i.).

b. *Supply Voltage Requirements.*

The Auxiliary Power Supply and the Pressurized R-F Unit are designed to operate over a greater range of supply voltages than that specified for the AN/APS-15A equipments.

c. *Mechanical Clearances.*

Effective protection from vibration requires that ample clearance be maintained between the unit and surrounding objects to prevent physical contact during the normal flexing of the vibration mounts. If this is not done the shock of sudden snubbing may cause greater accelerations than those caused by the vibration of the airplane.

d. *Tuning Search Local Oscillator.*

The Pressurized R-F Unit is adjusted at the factory using a transmitter which operates at approximately 9375 megacycles per second. The transmitter frequency of the AN/APS-15A equipment with which the R-F Unit is to be installed will probably be slightly different from that used at the factory. In this case, the cavity of the 723/AB (or 2K25) *search* local oscillator (V-14 of Figure 8-4) will probably have to be slightly retuned. The procedure for tuning the search LO is described in section V, paragraph 8.

III. OPERATION.

1. *Functions of Equipment.*

The basic functions of the AN/APS-15A equipment are not altered by the addition of the Replacement Pressurized R-F Unit. Beacon operation is simplified and rendered more useful by the provision of automatic frequency control for "tuning-in" beacons and by an increase in beacon range resulting from improved r-f components.

2. *Location and Function of Controls.*

Only two changes have been made in the function of existing controls, no controls have been moved, and no new controls have been added. The A-scope switch no longer gives the AFC discriminator output in position 3, this position gives nothing when the Pressurized R-F Unit has been installed. The function of the AFC-Manual switch (located on the R78/APS-15A Receiver-Indicator) has been extended to include automatic frequency control for beacon as well as search operation, when that switch is in the AFC position and the Search-Beacon switch is in the Beacon position.

3. *Starting.*

The starting procedure for the AN/APS-15A is not changed.

4. *Stopping.*

The stopping procedure for the AN/APS-15A is not changed.

IV. THEORY OF OPERATION.

1. *Functional Analysis of the Replacement Pressurized R-F Unit.*

a. *General.*

The AN/APS-15 radar system performs two general functions: the detection and location of targets within a certain area determined by the system's design and performance (*search or radar operation*), and the detection and location of one or more ground-based beacon stations by means of signals exchanged between the beacons and the interrogating radar (*beacon operation*). The Pressurized R-F Unit, as a kit installation in the AN/APS-15A set, enables these two general functions to be performed with greater reliability and ease of operation than is possible in the original, unmodified system.

b. *Pressurized R-F Unit.*

The Pressurized R-F Unit (also called "R-F head") contains components which perform four specific functions in the complete radar set. These functions are described below:

(1) *Duplexing.*

The AN/APS-15 radar set uses the same antenna for transmission and reception. The transmitting and receiving channels join at the Transmit-Receive (TR) junction. When the transmitted pulse ("main bang") is directed to the antenna, wastage of transmitted power into the receiver channel must be avoided. Also, the receiver must be protected from overload and burnout (of crystals) due to the large amount of power in the main bang. The transmitted power is prevented from being dissipated in the receiver channel, and the receiver is protected from overload by the TR assembly.

When the microwave pulse reflected from a target ("echo pulse") returns to the system, dissipation of power in the transmitter channel must be avoided. The ATR box (Anti-TR) furnishes the means by which this dissipation is prevented. The TR and ATR boxes, together with the connecting waveguide which makes up the TR junction are combined in one unit which is called the "duplexer." The duplexer thus brings together three separate parts of the radar: the transmitter, the receiver, and the antenna.

(2) *Conversion.*

The receiver is of the superheterodyne type, and radar or beacon pulses must be converted from radio frequency (r-f) to intermediate frequency (i-f). This is done by combining local oscillator power with the received signal in a crystal mixer. The local oscillator tube is tuned mechanically to the correct frequency region for receiving radar or beacon signals and is kept in tune by means of an automatic frequency control circuit. The input to the AFC circuit is at intermediate frequency and is obtained from one of two other crystal mixers (depending on the operating function at a given time), one for radar and the other for beacon reception.

(3) *Preamplification.*

The Signal Mixer output at i-f is amplified by the preamplifier. The i-f signals are then delivered to the AN/APS-15A receiver input via a 70-ohm coaxial cable.

(4) *Automatic Frequency Control.*

In the AFC chassis, Radar AFC (RAFC) Mixer output is used to control LO frequency for search operation, and Beacon AFC (BAFC) Mixer output is used to control LO frequency for beacon operation.

c. *Auxiliary Power Supply.*

The Auxiliary Power Supply is necessary to furnish the R-F Unit with the necessary B-plus voltages at current capacities which are not available from the original AN/APS-15A power supplies. The additional supplies necessary are:

plus 105 volts at 30 milliamperes
plus 150 volts at 35 milliamperes.

These are located on an additional sub-chassis which is installed in the indicator power supply unit.

2. *Pressurized R-F Unit.*

a. *R-F Components.*

The r-f components include:

Waveguide connection ("R-F Plumbing")
TR Box
ATR Box Duplexer
RAFC Attenuator
RAFC Mixer
Signal Mixer
BAFC Mixer Converters
Search LO
Beacon LO
TR Tuning Plunger and Associated Relay
BAFC Reference Cavity
Wave Selector

The r-f components in the R-F Unit function very much as in the r-f portion of the original AN/APS-15A; however, there are several changes and refinements.

The TR assembly protects the signal crystal from main bang power overload by producing a short-circuiting arc between the transmitter channel and the signal crystal during the transmitted pulse. The arc is initiated when the large voltage of the transmitted pulse is applied across the TR cavity. The short circuit is reflected to the TR junction so as to produce the effect of an open circuit at that point. Only the small amount of power necessary to maintain the arc is taken into the receiver channel from the main bang. Unlike the original APS-15, the Pressurized R-F Unit does not use the small portion of main bang energy which leaks through the TR assembly for AFC. In order that an arc may be established quickly when the main bang reaches the TR box, it is necessary to maintain a supply of gas ions in the tube. This is done by means of a small continuous gas discharge between a pointed electrode and the cavity wall (the "keep-alive"). A half-wave selenium rectifier system (the "keep-alive supply") furnishes the 400 volts at 200 microamperes used for the discharge.

The arc extinguishes after the main bang, and echo signals are allowed to pass through the TR section. The ATR box performs its usual function of reflecting r-f power (echo signal or beacon signal) to the transmit-receive junction and produces the correct impedance at the junction so that negligible echo energy is lost down the transmitter channel.

Main bang energy for search AFC is obtained by tapping off the main waveguide, through an r-f attenuator section (RAFC attenuator) into a separate AFC mixer. The search LO feeds both the signal mixer (r-f echo or beacon signals pass through the TR box to the signal mixer) and the RAFC mixer.

A third mixer is used for beacon AFC. The beacon LO feeds the signal mixer directly, and feeds r-f energy through a tuned high-Q cavity (BAFC cavity) into the BAFC mixer.

Beacons transmit on a frequency different from those used by airborne radar systems. If the TR cavity is tuned to one of these frequency bands a transmission loss is suffered by signals at the other frequency, since the TR is not broad-banded enough to accept both frequencies. A tuning stub or slug operated by a two-position relay is used, therefore, to retune the TR cavity for beacon reception. For search, the stub is pulled out of the cavity and does no tuning. The slight difference of tuning, which is so important for receiving signals, has little effect on the breakdown characteristics of the TR tube during the main bang.

A situation similar to that of the TR cavity tuning exists in the case of the ATR box. The ATR cavity tuning and its distance from the TR junction are both important to the maximum utilization of received signal power. If the ATR does not produce the correct impedance (zero) at the TR junction for both beacon and echo signals, then one of these functions will suffer by wastage of signal energy in the transmitter channel. The Pressurized R-F Unit incorporates a broad-band ATR tube, which further increases beacon receiving sensitivity over that of the original AN/APS-15A equipment.

A wave selector is provided to facilitate testing the R-F head. This is sometimes called a directional coupler because it provides a means of taking energy from the R-F head or feeding in a test signal with negligible effect from or to energy passing the wave selector in a direction away from the R-F head.

b. *Search Reception with Manual Tuning.*

This operation is exactly the same as in the original AN/APS-15 equipment. The search LO oscillates and the beacon LO is turned off. The LO cavity is tuned (rough tuning) 30 mc *above* transmitter frequency, and reflector or repeller voltage control is used for fine tuning. An intermediate frequency of 30 mc is obtained, also, if the LO is tuned 30 mc *below* the transmitter. The AFC circuit works correctly only when LO frequency is *above* the transmitter frequency, however. For this reason, if the LO is tuned 30 mc *below* the transmitter it is called "wrong sideband" operation.

c. *Beacon Reception with Manual Tuning.*

This operation is also the same as in the original AN/APS-15 equipment. The beacon LO oscillates, and the search LO is turned off. The beacon LO cavity is tuned to a frequency 30 mc *below* beacon frequency and fine tuning is obtained by reflector voltage control. One of the advantages in use of the Pressurized R-F Head is that AFC is provided on beacon operation as well as on search.

d. *Search AFC.*

This function is performed in the same general manner as in the original AN/APS-15 equipment. As before, the control circuit uses gas tubes for the final link in the AFC chain, however, circuit details in the whole chain are very different from the corresponding AN/APS-15 units.

There are two main variations from the original AN/APS-15:

(1) *RAFC Mixer Power Coupling.*

The r-f main beng is tapped off from the transmitter channel through a waveguide attenuator. The attenuation (approximately 80 decibels) is set so as to give an optimum input to the RAFC mixer crystal. An optimum input exists for the following reasons:

I-f harmonics are produced at the mixer due to the non-linearity of the crystal and by the mixing of r-f harmonics present in the LO or magnetron outputs. For example, when the LO is 15 mc away from the transmitter, there are 15, 30, 45 mc, etc., components in the crystal output. This means that a 30 mc pulse output is obtained from the crystal when the LO is 30, 15, 10, 5, etc., mc away from the transmitter. If the harmonic 30 mc pulse were hig enough to fire the gas tube (V-4 in Figure 8-4) at the end of the AFC chain, the set might be automatically held at an IF of 15 mc or 10 mc, which would greatly decrease the overall sensitivity and range of the radar. The output of the AFC elements into the trigger gas tube may vary by a factor of 5 to 8 from set to set due mainly to variations in the transmitter power, crystal conversion gain, and IF amplifier gain. This makes it necessary to include a gain reserve in the chain design, i.e., the gain is adjusted so that with every component at peak performance, 10 times as much pulse voltage is delivered to the trigger tube grid as is needed to fire it consistently. With every component poor, pulse voltage at the trigger tube is just sufficient to fire it, i.e. just enough to control the LO frequency. In order that no harmonic component can control the frequency the largest harmonic must then be 1/10 or less of the voltage amplitude of the fundamental pulse output from the crystal. At the same time the fundamental must be as large as possible (the fundamental is the pulse output at 30 mc when the LO is 30 mc away from the transmitter), so that sufficient gain is possible in the chain with the smallest number of amplifier tubes. This optimum set of conditions occurs in the AN/APS-15 when the RAFC attenuator is set at about 80 decibels, and crystal current is set at 0.6 milliamperes.

This optimum setting is not possible with a single-mixer AFC (as was used in the original AN/APS-15), where the same crystal is used both for echo signal reception and AFC, since the TR tube attenuation varies from 0.8 to 1.5 decibels, and is not controllable in this range.

(2) *AFC Discriminator Circuit.*

The second variation in the AFC of the Pressurized R-F Unit from that of the AN/APS-15 equipment is in the type of frequency discriminator used. The essential parts of the circuit form what amounts to a bridge network at the intermediate frequency. See Figure 4-1-A. The type of circuit used here is called a C-coupled discriminator.

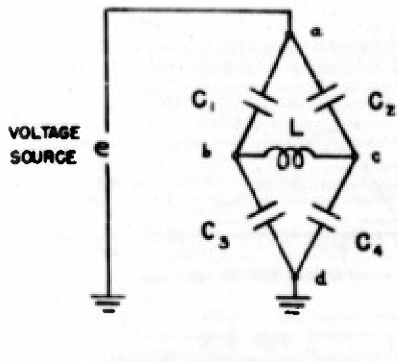


FIG. 4-1-A

AFC DISCRIMINATOR CIRCUIT, SCHEMATIC

Probably the simplest method of qualitative analysis is this: Change the delta network composed of C_1, C_2, and L into the equivalent Y-network. This procedure is schematically demonstrated in Figure 4-1-B.

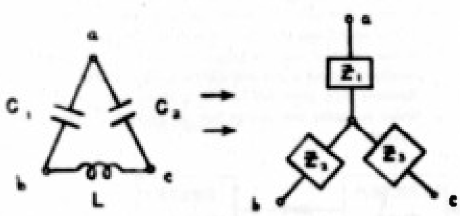


FIG. 4-1-B

CHANGE FROM THE C_1,L,C_2, DELTA TO THE EQUIVALENT Y CIRCUIT

The impedances Z_2 and Z_3 of the equivalent Y-network, which correspond to C_1 and C_2 of the original network, are inductive reactances, and are unequal in magnitude because C_1 and C_2 are not equal. If this Y-network is now combined with the remaining components of the discriminator circuit, as is shown in figure 4-1-C the frequency response of the circuit becomes apparent. Assume that Z_2 is the larger impedance; its value is set so that C_3 is series-resonant at a frequency lower then 30 mc (about 28.5 mc with the values used) and at this frequency maximum voltage is produced across C_3. Correspondingly, Z_3 is set so thet C_4 is resonated at a frequency higher then 30 mc (31.5 mc) and maximum voltage is produced across C_4 at this frequency. Diodes across C_3 and C_4 rectify the i-f currents to give d-c voltages across the diode load circuits. The diode loads are connected in opposition in the conventional manner, so thet the d-c output voltage is the difference between the separate diode voltages. The effective Q's of the tuned circuits are made fairly high, so thet at 28.5 mc there is negligible output contribution from the branch tuned at 31.5 mc and vice versa.

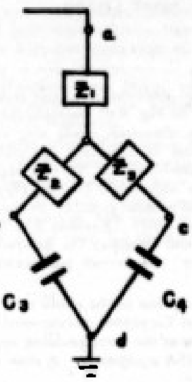
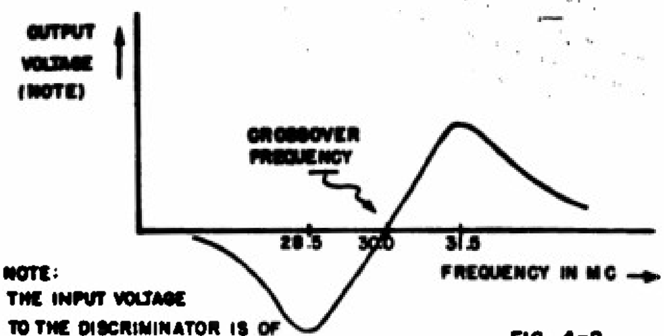


FIG. 4-1-C

EQUIVALENT CIRCUIT WITH C_1, L, C_2 DELTA REPLACED BY A Y

At a certain frequency between 28.5 and 31.5 mc the d-c load voltage (the difference of the diode load voltages) is zero. This frequency (30 mc) is the crossover point for the frequency discriminator. The discriminator output characteristic is given in Figure 4-2.



NOTE:
THE INPUT VOLTAGE TO THE DISCRIMINATOR IS OF CONSTANT AMPLITUDE AND VARIABLE FREQUENCY. OUTPUT IS TAKEN ACROSS THE DIODE LOADS.

FIG. 4-2
THE COMPLETE DISCRIMINATOR CHARACTERISTIC.

In the actual discriminator, the inductance (L in Fig. 4-1-A, L7 in Fig. 8-4) controls the crossover frequency. L7 is, therefore, made slug tunable, and is used occasionally in adjusting the AFC to top performance. Note—This is NOT a regular field adjustment. The inductance L6 (see Figure 8-4) tunes out the plate-to-ground capacity in the discriminator feeder amplifier (V6). Resistor R36 loads the plate circuit of V6 and broadens the bandwidth so as not to "pinch-down" the overall bandwidth of the AFC chain.

With the exception of the above new features (separate mixer and C-coupled discriminator), the search AFC is the same as the corresponding unit of the original AN/APS-15A equipment. A slow sweep voltage applied to the reflector of the search LO carries the LO frequency down toward the transmitter frequency until the proper beat frequency is reached, then the LO frequency is kicked upward by the trigger-tube action, the circuit recovers, and the frequency is swept downward again.

The sawtooth voltage which sweeps the LO frequency through the wide range necessary when the LO is searching for the transmitter frequency, before it has "locked in," is generated by a relaxation type oscillator using a gas tetrode tube (V3 in Figure 8-4). Resistor R13 provides feedback from plate to grid in order to make the sweep less dependent on tube variations.

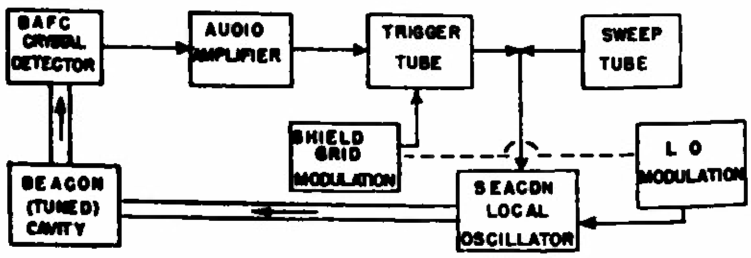


FIG. 4-3 BLOCK DIAGRAM OF BEACON AFC.

e. *Beacon AFC.*

There is no Beacon AFC in the AN/APS-15A equipment. A primary purpose in the design of the Pressurized R-F Unit is to provide beacon AFC, since its omission in the AN/APS-15 has been found to be a definite limitation of usefulness in operation.

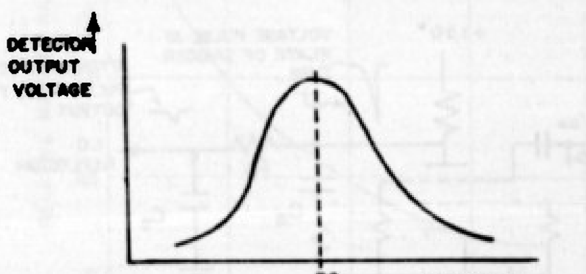
The general operation of beacon AFC (BAFC) is similar to that of radar AFC (RAFC). The LO frequency is caused to drift downward until it just passes the value for correct i-f, then an upward "kick" is supplied by the control circuit for a short interval, after which the circuit recovers from the surge, frequency drifts downward again, and the cycle is repeated. A block diagram of the BAFC is given in Figure 4-3.

The key unit in the BAFC is the beacon cavity. This is a high-Q tuned cavity at r-f, thermally compensated for temperature drifts. The center-frequency is 30 mc below beacon frequency, and the bandwidth at the half-power points of the cavity, loaded by the crystal mixer, is approximately 12 to 16 megacycles per second.

The BAFC crystal unit is used to detect r-f power generated by the beacon LO and passing through the cavity. As the LO changes frequency, power delivered to the crystal varies, being maximum when the LO is at cavity center-frequency and minimum when the LO frequency is either far above or far below this value, i.e., outside the cavity pass-band. Figure 4-4 gives the frequency characteristic of the beacon cavity. Here d-c voltage across the BAFC crystal is plotted against the LO frequency, in the cavity pass-band range.

When the signal frequency, f, into the cavity is below the center frequency, f_o, (on the sloping portion of the curve) a small increase in f, such as 1/10th of the frequency interval between f and f_o, results in a small *increase* in crystal voltage. When f is above f_o on the sloping portion of the characteristic, a small increase in f gives a small *decrease* in crystal voltage. When f is at the flat portion of the curve, (near f_o), there is *no change* in crystal voltage for a small change in frequency. The cavity-plus-detector arrangement may accordingly be used as a modulation-changer, that is, if an incoming signal of constant amplitude is frequency-modulated by a sine wave, voltage amplitude modulation corresponding to the frequency modulation (when the f swing is small compared to the cavity bandwidth) appears across the crystal, except near f_o where there is no change in crystal voltage for a small frequency swing and outside the pass-band where no power gets through the tuned cavity. On the low frequency side of the pass-band the crystal voltage a-c output is in phase with the frequency modulations, since the crystal voltage increases when frequency increases, and both reach extreme values at the same time. On the high-frequency side of the pass-band, crystal voltage is 180 degrees out of phase with the frequency modulation, since crystal voltage decreases as frequency increases and the voltage is minimum when frequency is maximum.

This 180 degree phase shift, above and below f_o, is the key to automatic control for beacon LO frequency. The LO is frequency-modulated by a small (0.6 volt peak-to-peak) 400 cycle voltage superimposed on the d-c reflector voltage. (0.6 volt p-p a-c on top of a d-c voltage of —160 volts, for example.) The result-



FO IS THE FREQUENCY TO WHICH THE CAVITY IS TUNED

FIG. 4-4. BAFC DETECTOR OUTPUT VS. BEACON LO FREQUENCY OR, THE BAND-PASS CURVE FOR THE BEACON CAVITY ing 400 cycle voltage output of the crystal is amplified up to a size convenient for working the control grid of the trigger gas tube in the AFC chain. When average frequency is shifted from above to below f_m, the crystal output voltage changes phase by 180 degrees.

A constant 400 cycle voltage is also applied to the shield grid of the trigger tube (V4 in Figure 8-4). If both grid voltages applied to the trigger tube are in phase (positive at the same time), then the gas tube fires. If the two grid voltages are 180 degrees out of phase, the control grid positive swing cannot fire the gas tube, since the shield grid is negative at the same time and prevents firing. (The d-c grid biases and the shield voltage swing are adjusted so that the tube cannot fire with only shield a-c voltage supplied.) This might be called a "coincidence detector," since the gas tube does not fire unless both grid signals are coincident, or in phase.

The phases of the modulation voltages are so fixed that when the average LO frequency is above f_o the gas tube does not fire and below f_o the gas tube does fire (provided that it is at the correct point on the beacon cavity characteristic). The beacon trigger tube circuit is shown in Figure 4-5.

When the trigger tube fires, the fast negative pulse produced at its plate is attenuated by the RC filter in the plate circuit and then applied to the LO reflector (refer to Fig. 4-5). This voltage pulse pushes the LO frequency upward to a point slightly above f_o during the pulse. When the voltage across V4 has dropped due to the discharge of condenser C8, the gaseous arc in the trigger tube extinguishes and the voltage across C8 builds up again toward the value set by the resistance bleeder (resistors 24, 21, 13, 15a, 15b, 18, 17, and 16 in Figure 8-4) between plus 150 and minus 250 volts. This equilibrium point is never reached, however, since as soon as this voltage (which is applied to the reflector) gets far enough so that LO average frequency is below f_m, the gas tube fires again and delivers another opposing pulse. The cycle is now complete and the LO frequency is automatically controlled. The RC filter (formed by R14, R12, and C5) is adjusted so that the maximum frequency shift during BAFC is about 1 mc, approximately centered at f_o, the cavity center-frequency (which, to repeat, is 30 mc below beacon frequency). The BAFC is, thus, completely contained in the R-F Unit, and does not depend in any way on the beacon transmission signal. This situation makes strict tolerance requirements in both machine work and materials in the manufacturing of the beacon cavities, and is solved by thermal and heavy metal construction.

f. Preamplifier.

The preamplifier unit receives the i-f signal from the signal mixer and amplifies it by a factor of 30. The output i-f signal is delivered on a 70-ohm line to the main i-f amplifier in the Receiver-Indicator unit. The preamplifier has the same gain as the corresponding unit in the original AN/APS-15A equipment, but has about twice the bandwidth (6 to 8 mc now). This extra bandwidth does not change the overall i-f bandwidth of the modified system appreciably, since the I-F strip of the Receiver-Indicator is only 3 to 5 mc wide. The extra bandwidth was built into the preamplifier to provide for a greater range of use for the Pressurized R-F Unit.

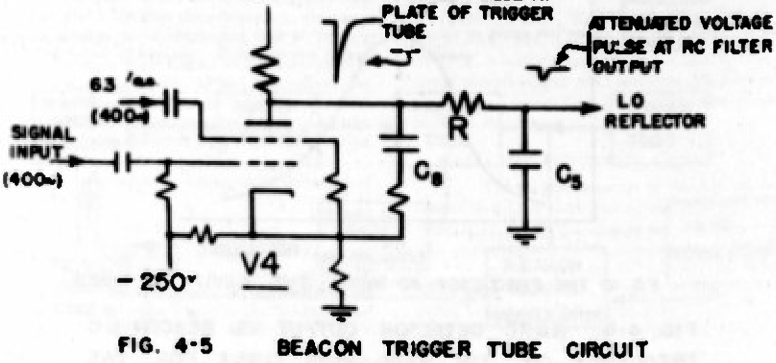


FIG. 4-5 BEACON TRIGGER TUBE CIRCUIT

V. MAINTENANCE.

1. *General.*

a. *Radar Performance.*

The problem of radar maintenance is one of attaining and maintaining peak performance. Under combat conditions this overall picture is often sacrificed to the more urgent need of keeping a maximum number of radar sets operative; thus, maintenance is often restricted to trouble shooting, and is resorted to only under urgent circumstances. Such a procedure is often further enforced by a lack of the necessary and adequate test equipment to perform a thorough maintenance job. However, most maintenance men endeavor to "tune-up" a set, and there have existed among them a variety of concepts of "good" radar performance and how to judge it.

Radar performance is, by definition, the ratio of the peak power output of the transmitter to the weakest signal power which the receiver can detect: p°/S_T. In practice, S_T is the minimum discernible test signal power, or the tangential test signal power; or the CW test signal equal to noise signal power; and may be correlated with the minimum discernible received signal power depending upon the method of testing used and such variables as the pulse recurrence rate, the sweep speed, the spot size on the indicator, and the type of presentation. This ratio, expressed in decibels, is the radar performance figure, which is a measure of the ability of the radar system to detect targets with a given set of external conditions.

Assuming constant external conditions, for example a target in free space, it is possible to correlate changes in maximum range with changes in radar performance by using the inverse fourth power law, viz., that the power received from a target is inversely proportional to the fourth power of the range to the target. Since the power of a returning signal is always proportional to the power in the transmitted pulse this law may be written

$$S_r = K_1\, p^{\circ}/R^4, \text{ or } R_{max} = K\sqrt[4]{p^{\circ}/S_{r\,min}},$$

Where S_r is the power received from a target at range R, p° is the peak transmitted power, R_{max} is the maximum range obtainable when $S_{r\,min}$ is the minimum discernible signal power, and K_1 and K are constants depending upon the characteristics of

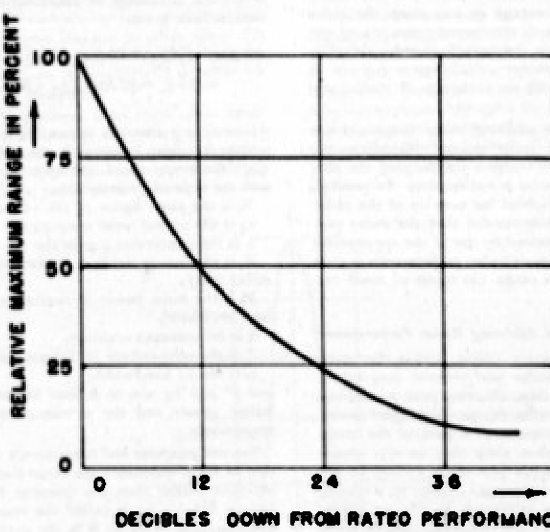


FIG. 5-1 RELATION BETWEEN RELATIVE RANGE AND RADAR PERFORMANCE FOR AN ISOLATED TARGET IN FREE SPACE.

the target and the design factors of the radar system. This relationship of maximum range to performance is illustrated graphically in Figure 5-1, where maximum range (expressed in percent of rated maximum range) is plotted against decrease in radar performance figure (expressed in decibels below rated value).

It may be useful to point out that a decrease of 6 db (decibels) in radar performance (which is not uncommon in practice) results in a decrease of 25 percent in maximum range.

A priori, the performance of a radar system may be judged on the basis of the maximum range obtainable, and any gross loss in radar performance, such as 12 db, will be apparent to an operator who is accustomed to the radar system in operation. However, it is not possible to measure radar performance accurately by observation of the maximum range, since in general complete information on the external factors affecting range is not available. The external factors which affect range are: 1) the reflection properties of the target, 2) the propagation pathway (difference in path length between reflected rays which may cause the rays to reinforce or cancel depending upon differences in path length), and 3) atmospheric conditions, such as temperature and humidity effects which may attenuate the r-f energy or may cause the radar beam to be bent upward, thus rapidly dissipating the energy in the beam, or downward, thereby delaying the dissipation of the energy. A change in any one of these conditions appears as a change in radar performance.

The external factors affecting radar range are not controllable from the radar system. Consequently, utilization of "standard" targets for judging the performance of a radar system is not reliable. In general, "standard" targets are useful for tune-up of the radar system only. It is recommended that the radar performance figure be measured by use of the appropriate test equipment. Maximum radar performance is thus attained and maximum range (in terms of rated values) is assured.

b. *Internal Factors Affecting Radar Performance.*

The internal factors (those within the radar set) which influence radar performance may be divided into two classes: those affecting peak transmitter output power and those affecting received signal power. Waveguide losses are treated as a part of the transmitting or receiving losses, since they usually appear as such in the maintenance procedure. Fixed or design factors, such as antenna gain, antenna scanning loss, or radome loss, are neglected; so also are operator losses, such as result from improper receiver gain, PPI bias, or focus control settings, since these factors cannot be ascertained or remedied by the maintenance personnel.

The peak power output of the transmitter is dependent upon the following: 1) the quality of the transmitter tube (spectrum); 2) the magnetic field strength; 3) the pulse peak voltage applied to the transmitter tube; 4) the pulse shape of the pulse peak voltage applied to the transmitter tube; 5) r-f losses in the waveguide, rotating joint, or antenna in the form of leakage, absorption, or arcing due to improper fitting of components, foreign material in the line, or reduced pressure at high altitude; and 6) r-f losses due to detuned or non-firing TR or ATR.

Receiver signal power is dependent upon the following:

1) quality of the crystal (gain and noise); 2) local oscillator tuning; 3) AFC performance; 4) TR and ATR tuning and losses in either of these; 5) noise of the local oscillator; 6) noise of the i-f amplifier; 7) waveguide, rotating joint, and antenna losses; and 8) the factors which determine how far into the noise a signal can be seen, viz., i-f bandwidth, pulse recurrence rate, sweep speed, spot size, and type of presentation.

The following equation relates most of the above factors in what may seem a formidable manner, but it has the advantage of breaking the problem down into its basic parts.

$$10 \log p^{\circ}/S_T = 10 \log p^{\circ} - [10 \log kT\Delta\nu + M + R + L + 10 \log (t_c + N_i - 1) + C],$$

where C is a constant depending upon the i-f bandwidth, the video bandwidth, the pulse recurrence rate ν_A, the sweep speed, the spot size on the indicator, and the type of presentation;

N_i is the noise figure of the i-f amplifier (a ratio);

t_c is the crystal noise temperature (a ratio);

L is the conversion loss in the crystal in decibels;

R is the loss in decibels in the duplexer (including mixer loss);

M is the noise power in decibels contributed by the local oscillator;

k is Boltzmann's constant;

T is the temperature in degrees Kelvin;

$\Delta\nu$ is the i-f bandwidth;

and p° and S_T are, as defined before, the peak transmitter power and the minimum discernible signal, respectively.

For test purposes and convenience of discussion, certain of these quantities are often combined into more inclusive terms; thus, the quantity $F = L + 10 \log (t_c + N_i - 1)$ is called the receiver noise figure and $N_r = F + M + R$ is the overall receiver noise figure (including r-f receiving losses). These quantities are expressed in decibels above the theoretical minimum noise, $kT\Delta\nu$.

It should be noted that $kT\Delta\nu$ is always less than 1, and that 10 log $hT\Delta\nu$ is thus always negative. For a receiver with 1 megacycle per second bandwidth, 10 log $kT\Delta\nu$ is approximately —114 dbm (decibels below 1 milliwatt), and if the receiver were ideal this would correspond to the minimum discernible signal power (equal to noise).

An assumption is made in expressing the radar performance figure as is done above; namely, it is assumed that the LO is correctly tuned and its power input to the signal mixer properly set, that the AFC is operating properly, that the TR and ATR are correctly tuned and operating, that the waveguide losses are small, that the modulator is operating properly, and that the magnetron spectrum is good.

The above equation indicates that the radar performance figure is determined if the peak power output of the transmitter, p°, the overall receiver noise figure, N_F, the overall receiver bandwidth, $\Delta\nu$, and the constant C are known. The bandwidth of the receiver is a design factor and is assumed constant unless there is a loss in receiver sensitivity which cannot be explained by a fault in receiver components. The constant C is more correctly a variable constant in that it depends upon several unknown factors, such as operating adjustments and cathode-ray tube characteristics. The most useful comment that can be made about this constant is that for a given operator, following an established test procedure, it is essentially constant for a given type of radar equipment.

The most readily obtained (and most often measured) factors which determine the radar performance figure are the peak power output, p°, and the overall receiver noise figure, N_F. These quantities completely tell of any change in radar performance; they also provide a preliminary means of localizing any losses present.

c. *Transmitter Performance.*

The transmitter performance figure is that part of the radar performance figure which depends on the transmitter; namely,

$$10 \log p^{\circ} \times .001 \text{ dbm (decibels above 1 milliwatt)}$$

where p° is the transmitter peak power output expressed in watts. For a transmitter with an 80 kilowatt peak power output the transmitter performance figure is 79 dbm.

In practice the average power output of the transmitter is usually measured and correlated with the peak power output by the relation

$$P_{av} = p^{\circ}\,\delta\,\nu_r,$$

where P_{av} is the average power output (measured with a power meter), p° is the peak power output (calculated), δ is the pulse width (measured with a capacity divider and oscilloscope, or a spectrum analyzer), and ν_r is the pulse recurrence rate (measured with an audio oscillator and oscilloscope). The term $\delta\nu_r$ is often referred to as the "duty cycle."

The transmitter may be looked on as a constant frequency oscillator which is periodically turned on and off by the modulator so as to produce pulses of r-f energy. Ideally, these pulses consist of an infinite number of continuous waves with amplitudes and frequencies dependent upon the pulse amplitude, pulse width, repetition frequency, and the frequency of the oscillator being pulsed. The spectrum of amplitude vs. frequency for an ideal transmitter is given in Figure V-2.

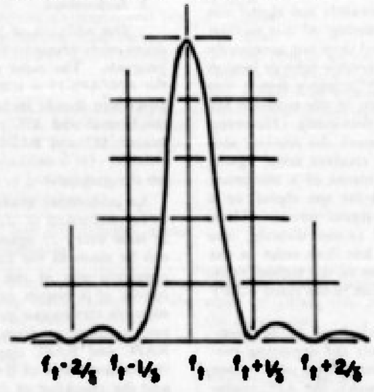


FIG. 5—2. DISTRIBUTION OF POWER IN AN IDEAL SPECTRUM

f_t IS THE TRANSMITTER FREQUEQUENCY.

A spectrum is considered good when 1) it is sufficiently stable, 2) its shape approximates the form given in Figure V-2, and 3) its width in frequency corresponds to the rated pulse width. In general, pulling of the magnetron frequency (due to r-f mismatches) or magnetron moding affect the spectrum drastically. A spectrum check (made with an echo box or spectrum analyzer) is necessary in adequate maintenance, for a poor spectrum will result in a decrease in peak power (and loss in range) which may not be detected when an average power measurement is made.

The pulse output of the transmitter (peak power and quality) is also, as stated before, affected by the pulse peak voltage applied to the magnetron, the pulse shape of the pulse peak voltage (both dependent on the modulator), and the magnetic field strength of the transmitter tube magnet. The characteristics of a magnetron of the type used in radar are such that there is very low tube (or anode) current for low pulse amplitudes, but there is a sharp rise in current as the pulse amplitude nears the operating region. Therefore, the chief requirements imposed on the modulator voltage pulse are that it must have the correct amplitude and a flat top (the sides are not very important). Pulse measurements are made with a capacity divider and an oscilloscope or synchroscope. The magnetic field strength (as measured with a fluxmeter) must be in the prescribed operating region.

d. *Receiver Performance.*

The receiver performance figure is that part of the radar performance figure which is associated with the receiving function of the radar set, namely,

$$-10 \log S_T \times .001 \text{ dbm}$$

where S_T is the minimum discernible test signal (in watts) as described at the beginning of this section, which is a measured quantity and does not necessarily correspond to the minimum discernible echo or beacon signal power. The receiver performance figure was divided into its basic components in the equation for radar performance figure given previously. However, it is the present practice to measure the receiver sensitivity rather than the overall receiver noise figure. This measurement is made by means of a minimum discernible test signal, a tangential test signal, or a CW test signal equal to noise signal power. Thus, rather than measure the noise power directly, one measures the power of a signal less than noise in the first method, equal to twice noise in the second (tangential) method, and equal to noise in the third (CW) method.

Other important factors which have to be measured in order to predict accurately the operating performance of a radar set are the transmitter peak power output on search and beacon (both), the AFC operation, the magnetron current, and the signal mixer crystal current.

The preceding discussion has been general in scope to the extent that it applies equally to all microwave radar systems which use magnetron transmitters and superheterodyne receivers. All have the same components and faults, and are maintained in the same general manner. The remainder of this section will be more specific in its treatment, although many of the statements are made capable of wider application than is indicated in the text.

e. *Maintenance Philosophy.*

The most useful tool to radar maintenance is an understanding of the function and value of each component, together with an eye and nose for trouble. To this end it is recommended that the maintenance personnel be acquainted with section IV of this manual and the same section of the AN/APS-15A Handbook of Maintenance Instructions. This type of information is best coordinated by a functional block diagram, such as is given in Figure 8-3.

Correct, rapid diagnosis of a specific trouble requires more than just understanding and information; it requires an insight which comes only with practice and familiarity with the radar set being serviced. A trouble shooting chart, such as is given in paragraph 6 of this section, is merely an orderly presentation of a common sense approach to each expected trouble, and will probably be resorted to only at first, when the set presents new features.

The proper use of the necessary and adequate test equipment is essential to proper maintenance, but without an understanding of the problem being undertaken, interpretation of the test results will not lead to the success that is usually hoped for and expected with this approach.

2. *Inspections.*

The addition of the Pressurized R-F Unit introduces no fundamentally new features to the inspection program. The same general approach recommended for AN/APS-15 is still applicable. The preflight test procedure should include a check of the operation of the beacon and AFC combination to be sure that the beacon LO and BAFC are not causing any apparent trouble. (It is unlikely that beacons will be observable on the ground.)

An additional routine inspection is recommended to be performed as often as is practically possible and at least every 25 operational hours. This inspection can be made in the aircraft without disconnecting or removing any of the radar components. It would consist of a system performance check which would measure transmitter power output on search and beacon, transmitter frequency, receiver sensitivity, and RAFC and BAFC operation. It might also include the measurement of RAFC and BAFC crystal currents, and the checking of the operation of the beacon TR tuning-plunger relay. The purpose of these tests was discussed in paragraph 1 and the test equipment to be

used is discussed in paragra

3. *Lubrication.*

No lubrication is nec
R-F Unit.

4. *Test Equipment.*

The following test e
maintaining maximum pe
Each item of test equipm

Item	
1. Echo Box (TS-62/AP)	Permit overal Detect Check
2. Power Meter (TS-36/AP)	Measu transm Can b box t ing n
3. Frequency Meter (TS-33/AP)	Measu of a Deter Must tors t
4. Signal Generator Test Set (TS-35/AP, TS-146/UP, TS-147/UP)	Meas beaco receiv con, Perm
5. Portable Oscilloscope (TS-34/AP, TS-239/UP)	Prov ger signa May oscil
6. Multimeter (TS-352/U)	Mea and
7. Spectrum Analyzer (TS-148/UP)	Disp with tran Mea tune

used as discussed in paragraph 4 of this section.

r. Lubrication.

No lubrication is necessary in the Pressurized R-F Unit.

s. Test Equipment.

The following test equipment is adequate for maintaining maximum performance of the r-f unit. Each item of test equipment is accompanied by a statement of the functions it performs, the rated value that should be obtained for maximum performance, and the minimum acceptable value below which the unit should be replaced or repaired. The first four items are connected to the unit through the 30 db directional coupler by means of a flexible cable whose loss is known.

In the use of test equipment it is expected that the test procedure given in the operating instructions for each unit will be referred to and followed.

TEST EQUIPMENT

Item	*Function*	*Rated Value*	*Minimum Value*
1. Echo Box (TS-62/AP)	Permits a quick, rough estimate of overall radar performance. Detects transmitter double moding. Checks RAFC operation.	23 microseconds (1.8 miles)	21 microseconds (1.6 miles)
		Note: Present echo boxes are rather insensitive and should be relied on only for rough measurements.	
2. Power Meter (TS-36/AP)	Measures average power output of transmitter or of a signal generator. Can be used in conjunction with echo box to localize a gross loss to receiving or transmitting function.	73 dbm on search 74 dbm on beacon	70 dbm on search 71 dbm on beacon
3. Frequency Meter (TS-33/AP)	Measures frequency of transmitter or of a signal generator. Detects double moding. Most useful for setting signal generators to approximate beacon frequency.	9375 mc plus or minus 30 mc/mc.	
4. Signal Generator Test Set (TS-35/AP, TS-146/UP, TS-147/UP)	Measures average power on search and beacon; receiver sensitivity on search and beacon, and transmitter frequency. Permits TR, LO, and RAFC tuning.	73 dbm 71 dbm —70 dbm —64 dbm	70 dbm 71 dbm —65 dbm —59 dbm
		9375 mc plus or minus 30 mc/mc. Tune to maximize signal from test set. AFC should stay locked in.	
5. Portable Oscilloscope (TS-34/AP, TS-239/UP)	Provides a means of observing trigger pulses, video wave forms, video signals. May be used as general purpose oscilloscope or synchroscope.		
6. Multimeter (TS-352/U)	Measures a-c and d-c voltages, ohms, and d-c milliamperes.		
7. Spectrum Analyzer (TS-148/UP)	Displays a picture of all frequencies, within a given band, radiated by the transmitter and local oscillator. Measures pulse width and the Q of tuned cavities.	Spectrum width between zeros on either side of the maximum: Search: 1.9—2.1, 1.1—.9 mc/mc. Beacon: .47—.52 mc	Should be within 10 percent of rated value. (See paragraph I of this section for correct spectrum shape.)

TEST EQUIPMENT (Cont.)

Item	*Function*	*Rated Value*	*Minimum Value*
8. Voltage Divider (TS-89/AP)	Provides a means of viewing voltage pulses greater than 200 volts in amplitude. The modulator pulse applied to the magnetron is the common voltage of this type.	Pulse width in μs: Search: .45—.55 .9—1.1 Beacon: 1.9—2.1 Pulse amplitude: 9.5 to 12 KV	Outside the range of rated values Less then 8.5 KV Over 12 KV indicates magnetron trouble
9. Fluxmeter (TS-15A/AP)	Measures magnetic flux density of the transmitter permanent magnet.	2500 gauss	2300 gauss
10. R-F Load (TS-108/AP)	Dummy r-f load for bench test purposes.		
11. Pressuriring Unit (MK-20/UP)	Hand pressurizing unit for checking pressurization of modulator, r-f unit, waveguide, and antenna unit.	Entire pressure system should hold a positive pressure of the order of 10 p.s.i. (gauge), with a drop of less than 1 p.s.i. in 24 hours. (This value, of course, depends on the capacity of any pressure pump which is attached to the pressure system in flight.)	

5. *Trouble Localization.*

If the r-f unit fails to operate properly the trouble should first be localized in a particular component. The following procedure will aid in the trouble localization.

a. *General Observation.*

(1) Inspect equipment for loose cables, bullet holes, dents, or other mechanical damage.

(2) Remove the cover from the head and inspect equipment for smoke, burned insulation or other evidence of electrical overload. (Use of the nose as an indicator is recommended in this connection; for, some light overload conditions do not produce visible smoke even though the odor of burned components is detectable.)

(3) Check operation of relays. There are 3 relays: RAFC to BAFC, AFC to Man., and the TR stub tuner relay. The first two may be checked by listening for clicks in the AFC chassis when the appropriate switches are thrown (RAFC to BAFC with Beacon-Search switch and Man. to AFC with AFC-Man. switch). The TR tuner may be checked visibly by observing the plunger move as the Beacon-Search switch is thrown.

b. *Operational Check.*

The performance of the r-f unit may be checked in the aircraft with the use of portable test equipment by measurement of currents, voltages, wave forms, and resistances. The four principal operations performed by the head may be checked separetely by switching. The principal operations are: 1) search reception on manual tuning, 2) search reception on AFC (RAFC), 3) beacon reception on manual tuning, and 4) beacon reception on AFC (BAFC).

If any gross fault exists, such as a bad tube or burned out resistor, it is usually possible to detect, or at least localize the trouble by observation of the components and their operetion, without the use of test equipment. This would involve turning on the set and trying the various operating combinations. BAFC faults are perhaps the least apparent without the aid of a small amount of extra equipment. For example, if the LO does not lock on in the RAFC combination, but sweeps through the region where signals are obtained; and if everything else seems to be working properly; then, the components to be examined closely are the RAFC attenustor, the RAFC mixer, the AFC i-f amplifier, the RAFC discriminator, and tubes V4 and V8 and their circuits. By this operetional check, even if the units have to be taken to a bench to be serviced, the service procedure is greatly simplified and time is saved.

If the fault is slight or involves several units so that localization is difficult without the use of test equipment, then it is likely that test equipment will be of use in finding the fault. Power supply voltages should be measured both at their source and at the terminals of all tubes which may be suspected of not operating properly. In particular the LO reflector voltages should be measured (using a high impedance voltmeter, such as the RCA volt-ohmist vacuum tube voltmeter), since this is the last point in a line of possible fault sources.

R-F receiving losses may be more difficult to isolate by logical test procedure. After the set has been tuned up as well as possible with the aid of test equipment (such as a signal generator and synchroscope), the final checking of specific components may be best accomplished by substitution.

6. *Specific Troubles.*

The trouble chart given below may prove useful in locating a defective circuit or component.

	Minimum Value
.1	Outside the range of rated values Less then 8.5 KV Over 12 KV indicates magnetron trouble
	2300 gauss

should hold a positive pres-
p.s.i. (gauge), with a drop of
ours.
depends on the capacity of any
attached to the pressure sys-

possible to detect, or at least
servation of the components
out the use of test equipment.
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ations. BAFC faults are per-
without the aid of a small
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be examined closely are the
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greatly simplified and time

involves several units so that
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suspected of not operating
LO reflector voltages should
impedance voltmeter, such
uum tube voltmeter), since
ne of possible fault sources.
be more difficult to isolate
After the set has been tuned
the aid of test equipment
nd synchroscope), the final
nents may be best accom-

n below may prove useful
it or component.

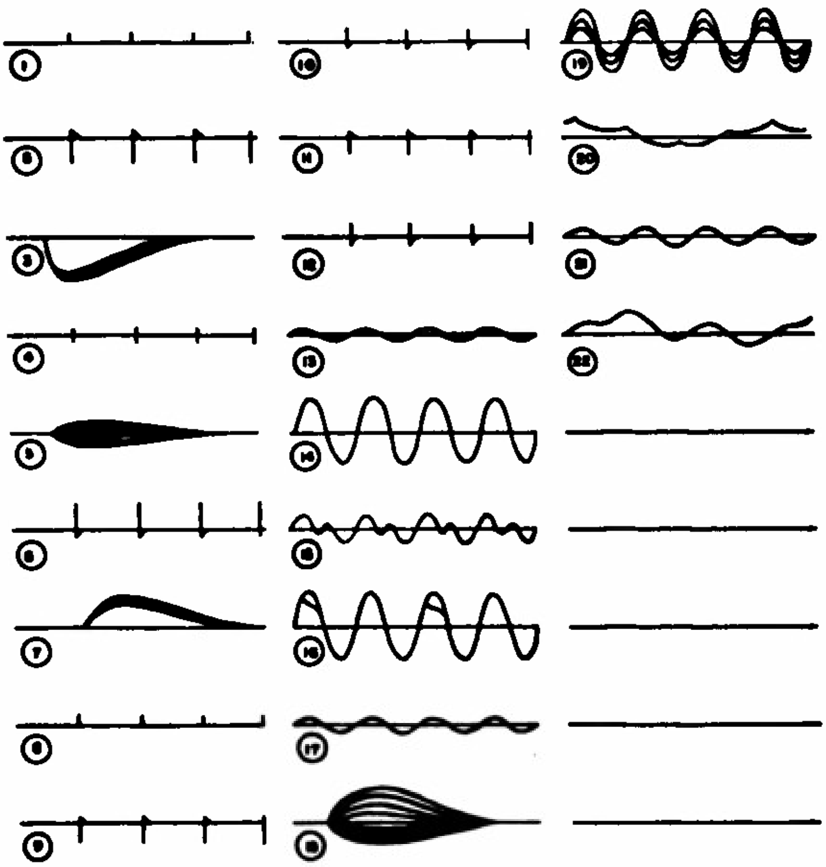
TROUBLE CHART

Symptom	*Observation Method*	*Usual Source of Trouble*
No i-f signal output	Connect i-f output from pre-amplifier to working AN/APS-15 receiver strip by 70 ohm shielded cable. Observe video output on A 'scope or synchroscope	Signal mixer crystal is bad or missing. Gain control is set at minimum gain. No preamplifier B plus or filiment voltage. Bad preamplifier tube (V9, V10, V11, Figure 8-4) or bad connection.
Main bang output, but no echo signals	Same	LO no oscillating or not tuned correctly.
No crystal current	No crystal current meter reading for any setting of the manual tuning knob, for signal or RAFC mixers.	LO not oscillating. Not tuned correctly. No B plus or heater voltage to LO. LO adjustable couplers to mixers not adjusted correctly. Short or open in crystal current circuit.
Radar AFC not holding (crystal current sweeps, but no locking or intermittent locking)	Crystal current meter	Insufficient power from LO to RAFC mixer. Coupler needs adjustment. LO cavity improperly tuned. Bad tubes V5, V6, V7, V8, V4, or bad connection. Search sweep potentiometer not set to sweep through correct reflector voltage range.
No search sweep on AFC but sufficient crystal current on Manual operation	Crystal current meter Reflector voltage (as shown by high impedance voltmeter) not sweeping	Bad gas tube V3, or fault in sweep tube circuit.
RAFC not holding (signal crystal current sweeps, but no locking)	Crystal current meter	LO cavity tuning off. Bad or no BAFC crystal. Search sweep pot. not adjusted to correct reflector voltage range. Bad tubes V1, V2, V4, V8, or bad connection.
RAFC locks, but signals much weaker then those on manual tuning	Radar 'scope or test 'scope	LO incorrectly tuned—AFC locking on wrong sideband.
AFC locks at much lower crystal current then that on manual tuning	Crystal current meter	LO cavity tuning off. Search sweep pot. set at different LO mode than that used on manual.
Crystals burn out immediately on insertion in set	Crystal tester, after crystal has been used with set running	No keep-alive voltage in TR tube. Bad TR tube

7. *Wave Forms.*

In trouble shooting the r-f unit, it will often be of great assistance to observe certain voltage wave forms. Test points of particular interest are the control grid o fthe gas tube V4 (Figure 8-4) and the reflectors of the local oscillator tubes. The voltage wave forms at these points for certain conditions are given in the following pages. The wave forms given are for a head which is operating properly. The switch positions corresponding to the illustratetd wave forms are given, and both are numbered the same.

A CRO (cathode ray oscilloscope) and a synchroscope, or a combination such as the TS-34/AP are recommended test equipment for this purpose.



TYPICAL WAVEFORMS OF A PROPERLY OPERATING R-F HEAD, AS DESCRIBED IN TEXT.

EXPLANATION OF WAVE FORM CHART

Condition	*Values*	*Scope*	*Remarks*
Head tuned up and working correctly			Wave forms observed at grid to trigger tube V4
Search reception with manual tuning.			
1) Manual tuning knob set outside of LO mode, on the high frequency side. (Reflector voltage more negative than in oscillating mode.)	At most, 1 to 2 volts peak	CRO with X-axis sweep at about ¼ the system rep. rate	Residual pulse pickup
2) Manual tuning approaching signal frequency from the high frequency side	Peak value approximately 50 volts (CRO too slow to register this)	CRO with X-axis sweep at about ¼ the system repetition rate	Negative pulses which do not fire trigger tube. Small pos. overshoot is due to slow CRO response
3) Same as 2 above	Peak 50 volts	Synchroscope, synchronized with rep. rate	The synchroscope is fast and can measure this value accurately
4) Manual tuning at correct frequency, LO is 30 mc higher than transmitter	1 to 3 volts peak	CRO, same as 1 above	Both negative and positive pulses, since discriminator is not perfectly balanced (also residual pickup)
5) Same as 4 above	1 to 3 volts	Synchroscope, same as 3	Accurate voltage measurement is possible
6) Manual tuning below signal frequency, but still within mode	Peak value 50 volts (same as 2 above)	CRO, same as 1	
7) Same as 6 above	Peak value 50 volts	Synchroscope, same as 3 above	
8) Manual tuning outside of mode on low frequency side	1 to 3 volts	CRO	Residual pickup
9) Manual tuning, frequency outside of fundamental range (outside discriminator characteristic), but approaching a frequency 15 mc above transmitter from high freq. side	10 volts peak	CRO	2nd harmonic production of 30 mc signal
10) Same as 9, but going out on low frequency side of 2nd harmonic point	10 volts peak	CRO	2nd harmonic
11) Repeat of 9 at 10 mc difference between LO and transmitter	5 volts peak	CRO	3rd harmonic production of 30 mc signal

EXPLANATION OF WAVE FORM CHART (Cont.)

12) Repeat of 10 at 10 mc difference between LO and transmitter *Beacon reception with manual tuning.*	5 volts peak	CRO	3rd harmonic

Note 1—Wave forms produced by harmonic generation of 30 mc are present only on the low-frequency (least negative reflector voltage) side of the fundamental point.

Note 2—When sweeping through from high to low, neg. pulses come first, then positive pulses.

Note 3—If LO is on wrong sideband (below transmitter frequency), the harmonics will occur on the high frequency side of the fundamental point.

Note 4—If LO is tuned on wrong sideband, wave forms in Note 1 will be reversed in polarity (sweeping from high to low will give positive pulses first).

Condition	*Values*	*'Scope*	*Remarks*
13) Manual tuning knob set outside of LO mode on high frequency side (on the most negative reflector voltage side)	6 to 8 volts peak-to-peak	CRO, synchronized at about 100 cps	Residual hum
14) Manual tuning, approaching correct freq. from high side	40 to 100 volts, peak-to-peak	CRO, same as 13	
15) Manual tuning correct	6 to 8 volts, peak-to-peak	CRO	Residual hum plus double frequency production at cavity center frequency
16) Manual tuning, leaving correct freq. on low side	40 to 100 volts peak-to-peak	CRO	Break at positive peaks indicate trigger tube firing on some of the cycles
17) Manual tuning out of mode on low freq side	6 to 8 volts, peak-to-peak	CRO	Hum
18) *Search reception with AFC* (RAFC)	50 volts peak positive	Synchroscope, synchronized with rep. rate	Both neg. and pos. pulses as frequency sweeps back and forth over the cross-over point
19) *Beacon reception with AFC* (BAFC)	40 to 60 volts peak-to-peak	CRO, synchronized to about 100 cps	Break at pos. peak indicates gas tube firing on some cycles
Head tuned up and working correctly			Wave forms observed at reflectors of LO's. (The d-c reflector voltage is —120 to —190, so beware of damaging 'scope input condenser.)
20) RAFC	Extremes about ½ to 1 volt	CRO, synchronized to about 100 cps	This could be looked on as a frequency vs. time plot
21) Beacon manual tuning	About .6 volts, p-p at 400 cps	CRO, same	Showing voltage modulation which results in LO frequency modulation
22) BAFC	Extremes about ½ to 1 volt	CRO, same	Shows BAFC is operating. Is also a plot of freq. vs. time

8. Bench Adjustments.

It is possible to make the following adjustments without removing the r-f unit from the aircraft; however, some of them must be made before the Pressurized R-F Unit can be used, and it may be found simpler to do this on the bench. Bench tuning of the search LO and TR will require carrying the Transmitter-Converter (RT-15A/APS-15) with which the r-f unit is to operate to the bench also. Certain initial adjustments, which are a necessary part of the modification procedure, were mentioned in the installation section, these adjustments depend on the system with which the r-f unit is to be used and cannot be made at the factory. The adjustments necessary for the Pressurized R-F Unit which differ from those described in the AN/APS-15A Maintenance Instructions are the tuning procedure for the LO's, the AFC'S, and the TR cavity.

a. *Search LO Tuning Procedure.*

(1) Turn the Search-Beacon switch to Search.

(2) Turn AFC-Man. switch to Man.

(3) Make sure there are crystals in the signal mixer and the AFC mixers.

(4) Insert meter in RAFC crystal circuit.

(5) Connect leads from a CRO or synchroscope to the test point at the grid of trigger tube V4 and ground.

(6) Turn on power. Wait 3 minutes and turn on transmitter.

(7) Turn search LO buckling screw all the way out (use wrench clamped on side of AFC chassis), this tunes the LO cavity to the high frequency end.

(8) Slowly turn buckling screw in clockwise direction and at the same time rapidly swing the LO reflector voltage through the —120 to —190 volt range by means of the manual tuning knob.

(9) When signals show on the 'scope, adjust the buckling screw and manual tuning knob roughly to maximize the signal. (See wave forms of last paragraph.)

(10) Turn off transmitter and turn the AFC-Man. switch to AFC.

(11) Starting from the extreme counterclockwise end, turn the RAFC search sweep pot. (R28) slowly clockwise and observe the crystal current meter.

(12) When the sweep approaches the correct value, crystal current will fluctuate from zero upwards. Adjust the pot. to give maximum fluctuation of the meter.

(13) Now turn on the transmitter and the RAFC will lock.

(14) With RAFC locked, adjust the search LO buckling screw to give a maximum crystal current reading on the meter.

(15) Adjust the LO-to-RAFC mixer coupling screw to give a crystal current of .6 milliamperes. (Turning the coupling screw into the duplexer causes less power to be delivered to the crystal.)

(16) Put the crystal current meter into the signal crystal circuit (jack on power plug panel on base of r-f unit) and adjust the LO-to-signal mixer coupling screw to give .6 mil. crystal current.

(17) Switch back to manual tuning and observe the sequence of pulses on the 'scope as tuning is swept through the mode from high to low frequency. This sequence should be as illustrated in the preceding paragraph. If the sequence is not as shown, the buckling screw has been turned too far clockwise (has been adjusted to tune to the wrong sideband), and the tuning procedure should be repeated from (7) above.

b. *Beacon LO Tuning Procedure.*

(1) Turn Search-Beacon switch to Beacon.

(2) Turn AFC-Man. switch to Man.

(3) Make sure there are crystals in the signal mixer and the AFC mixers.

(4) Insert meter in BAFC crystal circuit.

(5) Connect leads from CRO or synchroscope to the test point at the grid of trigger tube V4 and to ground.

(6) Turn on power. The transmitter need not be turned on.

(7) Turn beacon LO buckling screw about ¾ths of the way out (use wrench clamped on side of AFC chassis), this tunes the LO cavity to the high frequency end of the range.

(8) Slowly turn buckling screw clockwise and at the same time rapidly swing the LO reflector voltage through the —120 to —190 volt range by means of the manual tuning knob.

(9) Approach to the correct tuning range is indicated by a current reading on the meter. Adjust the buckling screw and manual tuning knob to give maximum current.

(10) Turn the AFC-Man. switch to AFC.

(11) Pull out tube V2.

(12) Starting from the extreme counterclockwise position, turn the beacon sweep potentiometer (R29) clockwise until crystal current shows (this will be fluctuating due to the AFC sweep). Adjust the pot. to give maximum fluctuation.

(13) Remove the milliameter from the BAFC crystal circuit, put V2 back in its socket, and BAFC will lock.

(14) Put a voltmeter across the BAFC crystal output (this is a jack fitting). The meter must have a high impedance in order not to load down the crystal. The voltage should be .2 to .4 volts. Adjust the buckling screw for maximum voltage.

(15) Adjust LO-to-signal mixer coupling screw (turning in causes less power to be delivered to the crystal) to give a crystal current of .6 milliamperes.

(16) Switch back to manual tuning and observe the sequence of wave forms on CRO as tuning is swept slowly through the mode from high to low frequency. This sequence should be as shown in the last paragraph. This is merely an auxiliary check, since the BAFC locks only at one frequency and there is an possibility of tuning to the wrong sideband.

c. *TR Tuning on Search.*

(1) Turn Search-Beacon switch to Search.

(2) Turn AFC-Man. switch to AFC.

(3) Turn on power. Wait 3 minutes and turn on transmitter.

(4) Turn A-scope switch to position 1. Adjust antenna to pick up echo signals, as observed on A-scope.

(5) With a screwdriver, adjust the TR tuning screw (located on TR box) for maximum signal height. For this purpose it is best to use a stationary, distant target. Make sure that the signal being observed on the A-scope is not limiting in the receiver, by turning the receiver gain down until the signal height goes up and down as the gain control knob is turned clockwise and counterclockwise.

d. *TR Tuning on Beacon.*

This is done at the factory, but if any of the r-f elements are changed (LO's, TR, etc.) the beacon TR tuning must be checked again.

(1) Turn on the power. Turn Search-Beacon switch to Beacon. Turn AFC-Man. switch to AFC.

(2) If a beacon is visible turn on transmitter and observe beacon signal. If no beacon is visible, a signal generator will have to be used; this signal generator should have a tunable oscillator (such as is in the TS-146/UP or TS-147/UP). The signal generator test signal will be coupled into the system through the wave selector. The transmitter may or may not have to be turned on depending on the signal generator used.

(3) Adjust the receiver gain or signal generator output (or both) until signals do not limit on the A-scope.

(4) With a screw-driver, adjust the tuning screw on the TR slug tuner relay to give maximum signal height on the A-scope.

Note: The tuning of the TR and the slug tuner is not very critical. The maximum signal height occurs over a broad range of tuning and it is best simply to adjust the tuning screws half way between the two points on each side where signals are first noticed to decrease.

9. *Removing and Installing Special Tubes.*

The problem of installation is obviously the reverse of removing. Since the Pressurized R-F Unit is delivered complete, attention here will be restricted to the removing of special tubes.

a. *TR Tube* (1B24).

(1) Remove keep-alive cap.

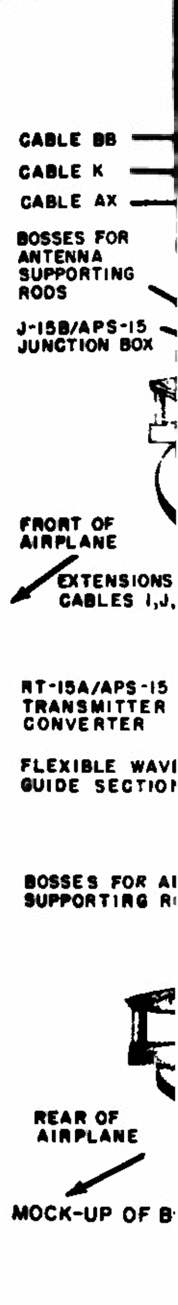
(2) Disconnect the signal and beacon i-f cables from the mixer.

(3) Remove the four screws holding the TR tube in place (two of these must be reached through holes in the AFC chassis).

(4) The TR tube will now slip out with a little careful rocking of the tube and springing of the mixer away from the tube.

b. *ATR Tube* (1B35).

Remove the two screws whose washers hold the ATR tube in place. Remove the tube by pulling it directly along the axis of the pull-rod with a minimum of rocking.



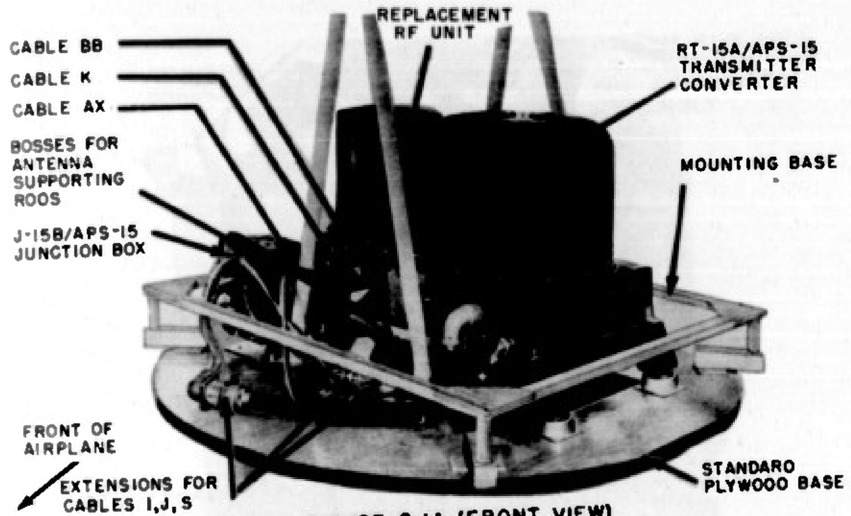


FIGURE 6-1A (FRONT VIEW)

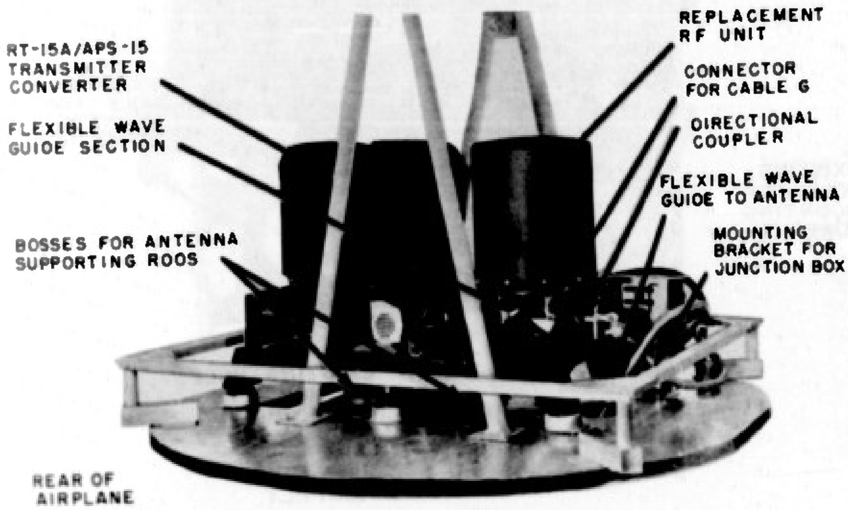


FIGURE 6-1B

MOCK-UP OF B-17 INSTALLATION OF AN/APS-15A WITH REPLACEMENT RF UNIT

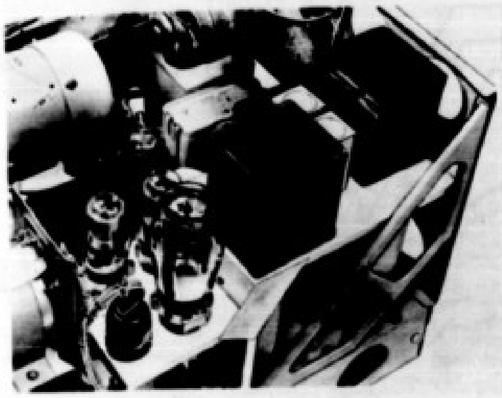
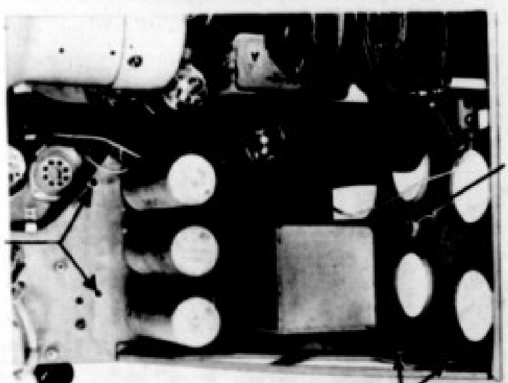


FIGURE 6-2A



EXISTING HOLE FOR MOUNTING POWER SUPPLY

EXISTING HOLES FOR MOUNTING POWER SUPPLY

EXISTING HOLES FOR MOUNTING POWER SUPPLY

FIGURE 6-2B

AUXILIARY POWER SUPPLY

MAGNET

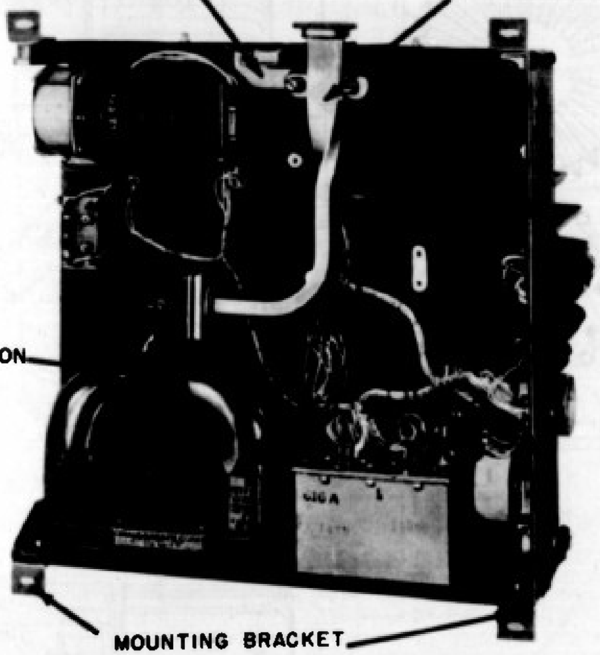


FIGURE 6-3

BOTTOM VIEW OF RT-15A/APS-15 TRANSMITTER CONVERTER AFTER MODIFICATION

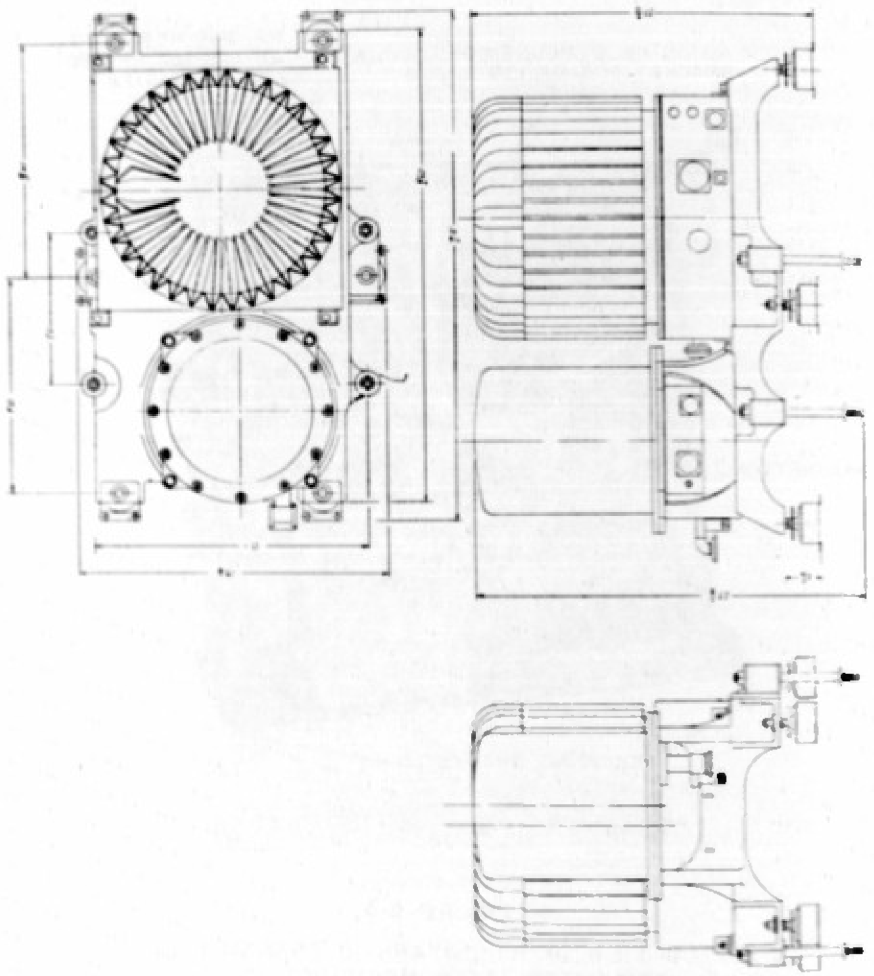


FIGURE 6-4 OUTLINE DRAWING OF COMPLETE ASSEMBLY

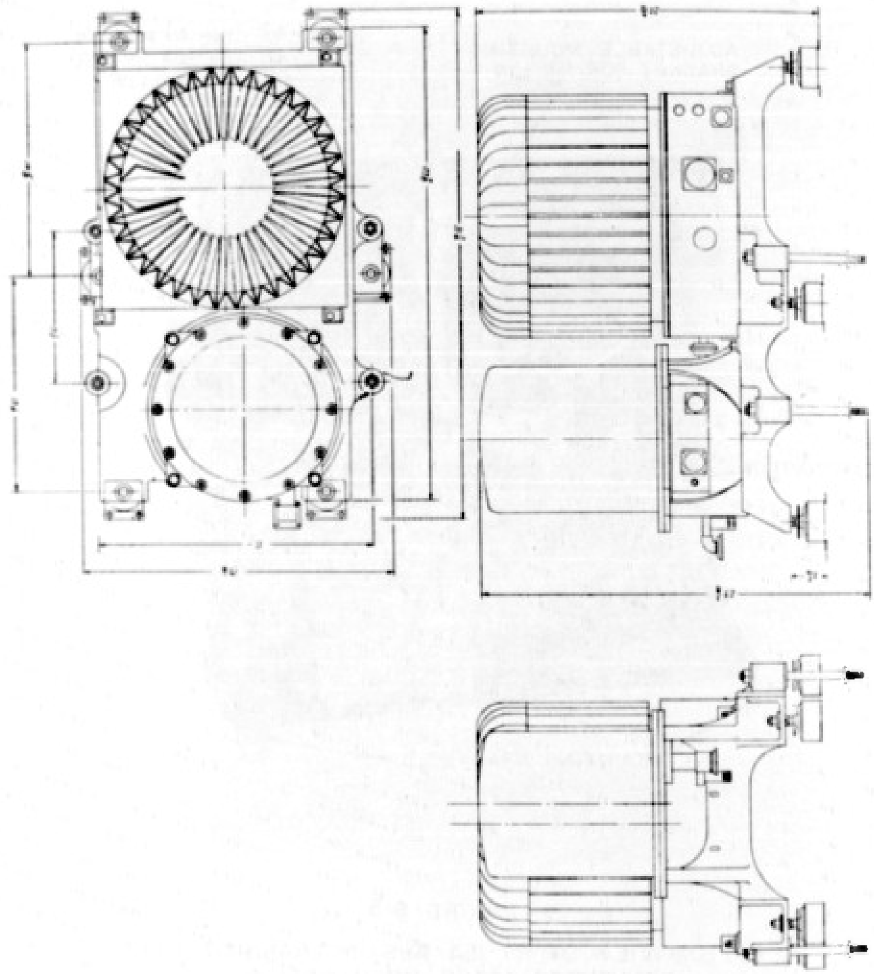


FIGURE 6-4 OUTLINE DRAWING OF COMPLETE ASSEMBLY

LAYO

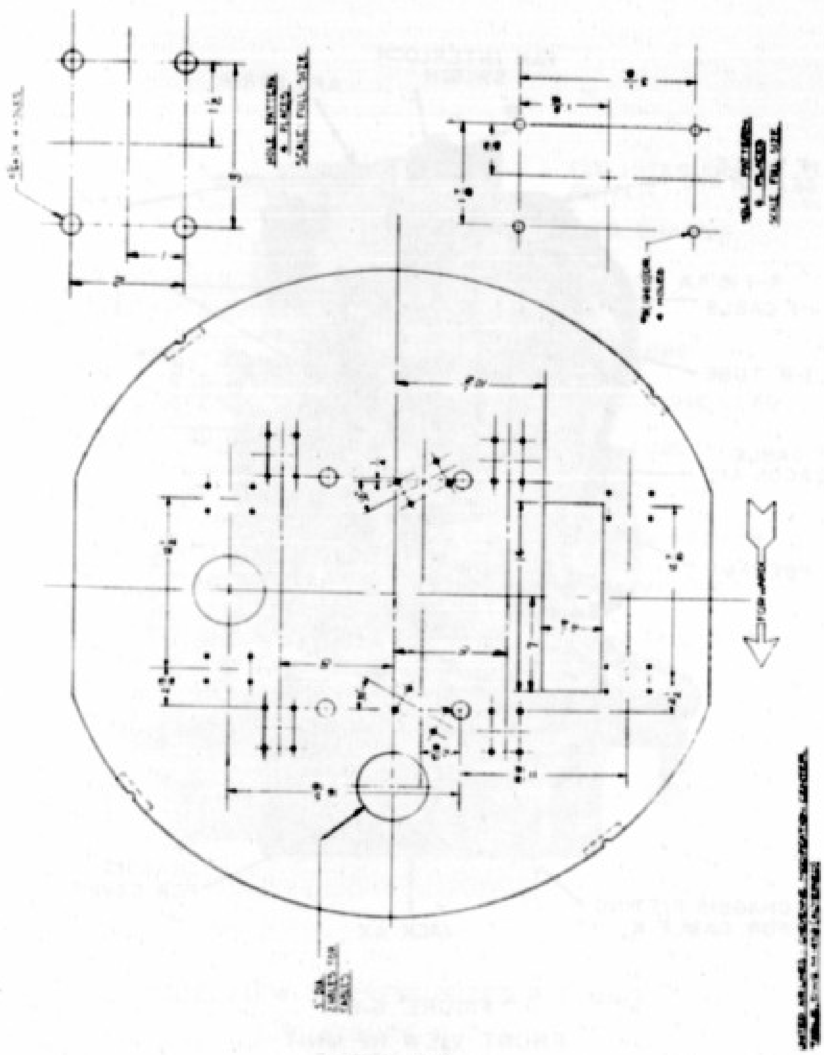


FIGURE 6-5
LAYOUT OF MOUNTING HOLES IN PLYWOOD MOUNTING PLATE

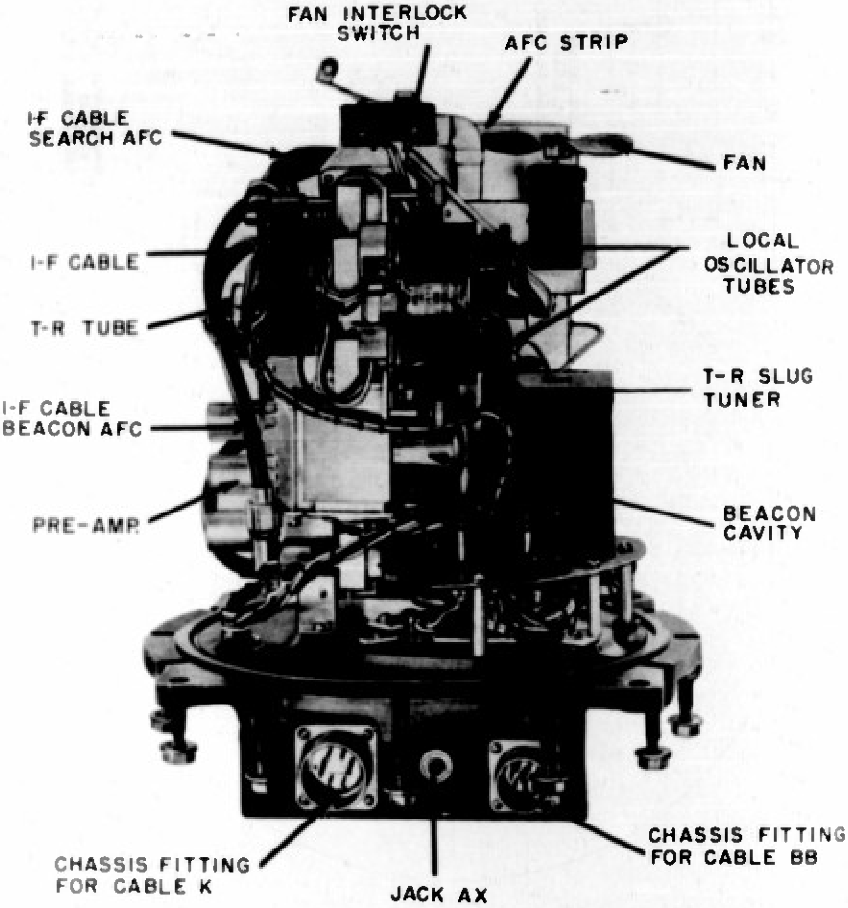
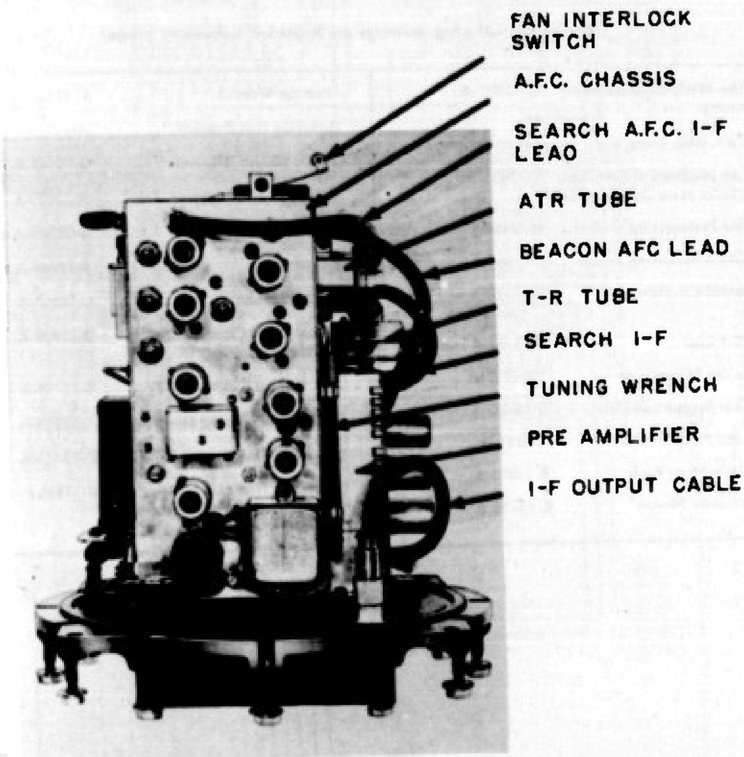


FIGURE 6-6
FRONT VIEW RF UNIT



SIDE VIEW OF PRESSURIZED R-F UNIT
FIGURE 6-7

VII. LIST OF DRAWINGS OF MECHANICAL AND ELECTRICAL COMPONENTS INVOLVED IN PRESSURIZED R-F UNIT MODIFICATION KIT

(Most of the following drawings are Radiation Laboratory prints)

R-F Unit Mechanical Assembly Drawing	D-12807-A	Tuning Wrench	C-13125-A
R-F Unit Base Plate	D-12807-C	Junction Box Bracket	A-14849-A
R-F Unit Mechanical Parts List (includes parts drawings list)	C-12807-B	Shock Mount Adapter	B-14849-B
R-F Unit Pressurizing Gasket	B-12807-J	90 Type N Connector	A-12609-A
Installation Mounting Frame	S-13664-A	Mixer	D-12705-A and P. L.
Directional Coupler	B-13120-A and P. L. (parts list)	Duplexer	A-12666-A and P. L.
Input R-F Line	C-13169-A and P. L.	Crystal Holder	C-12260-A
Bracket for Waveguide	TB-6137-A	Preamplifier Chassis Sub Assembly	B-12800-A
Clamp for Magnetron Line	B-13194-A and P. L.	AFC Chassis Sub Assembly	B-12953-A
Motor and Filter Bracket	T-6142-A	Installation Wiring Diagram	A-13534-A
Antenna Support Rods	B-14072-A	Schematic Diagram of R-F Unit	D-13423-A
Beacon Cavity Mount	C-13136-A	Schematic Diagram of Auxiliary Power Supply (Harvey Wells)	B-733-A

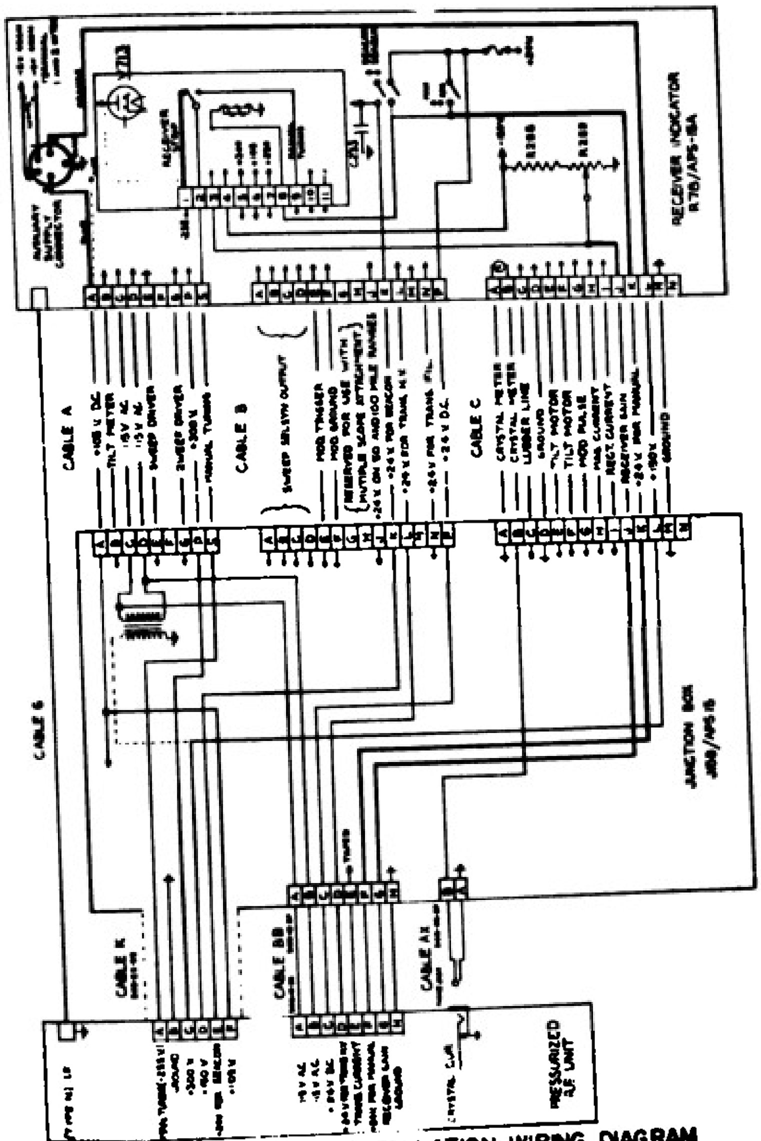


FIGURE 8-1 INSTALLATION WIRING DIAGRAM

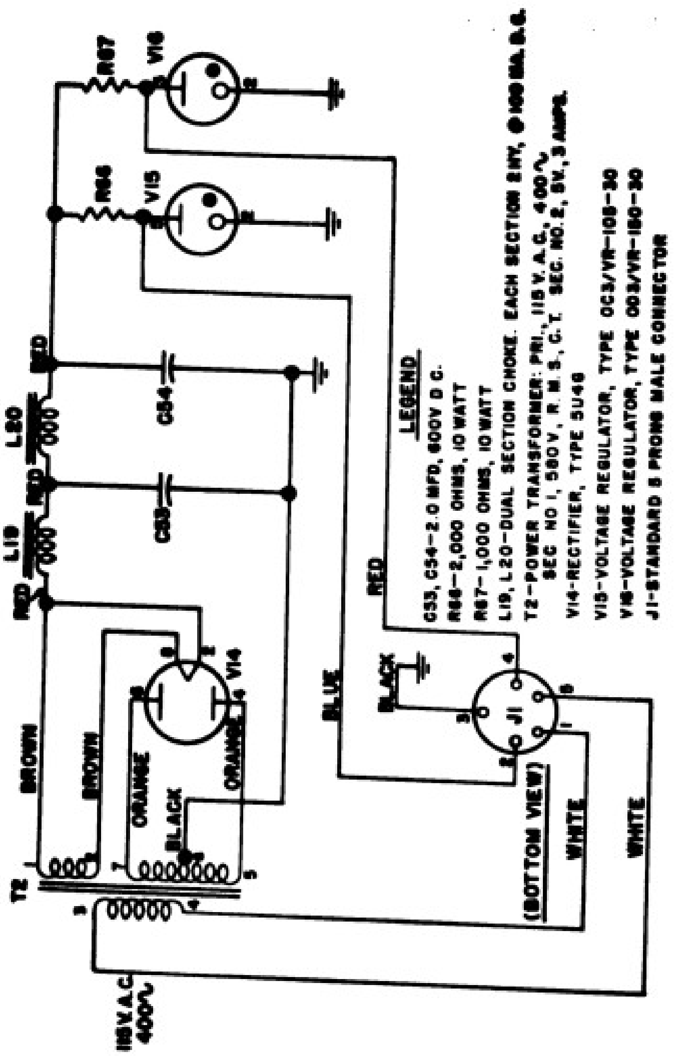


FIGURE 8-2 AUXILIARY POWER SUPPLY, SCHEMATIC DIAGRAM

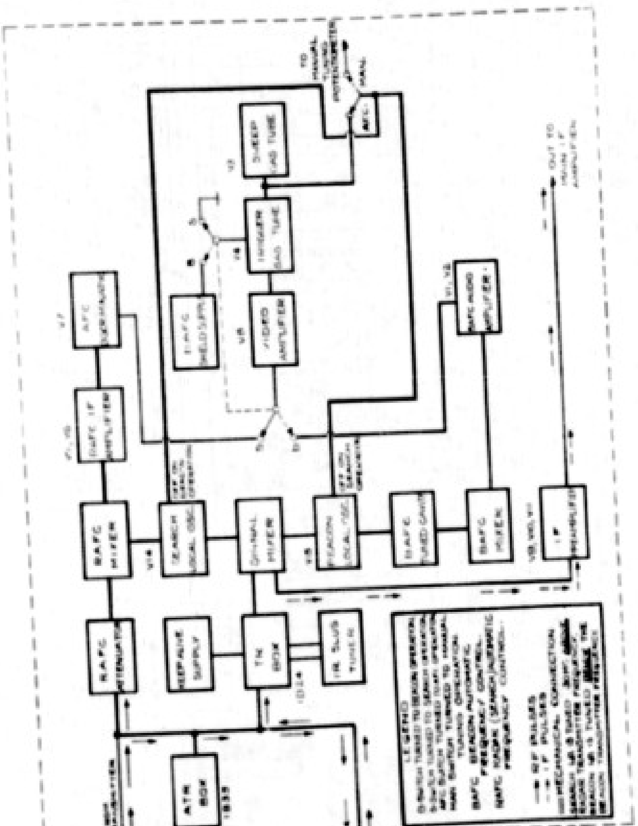


FIGURE 8-3 BLOCK DIAGRAM OF PRESSURIZED R-F UNIT

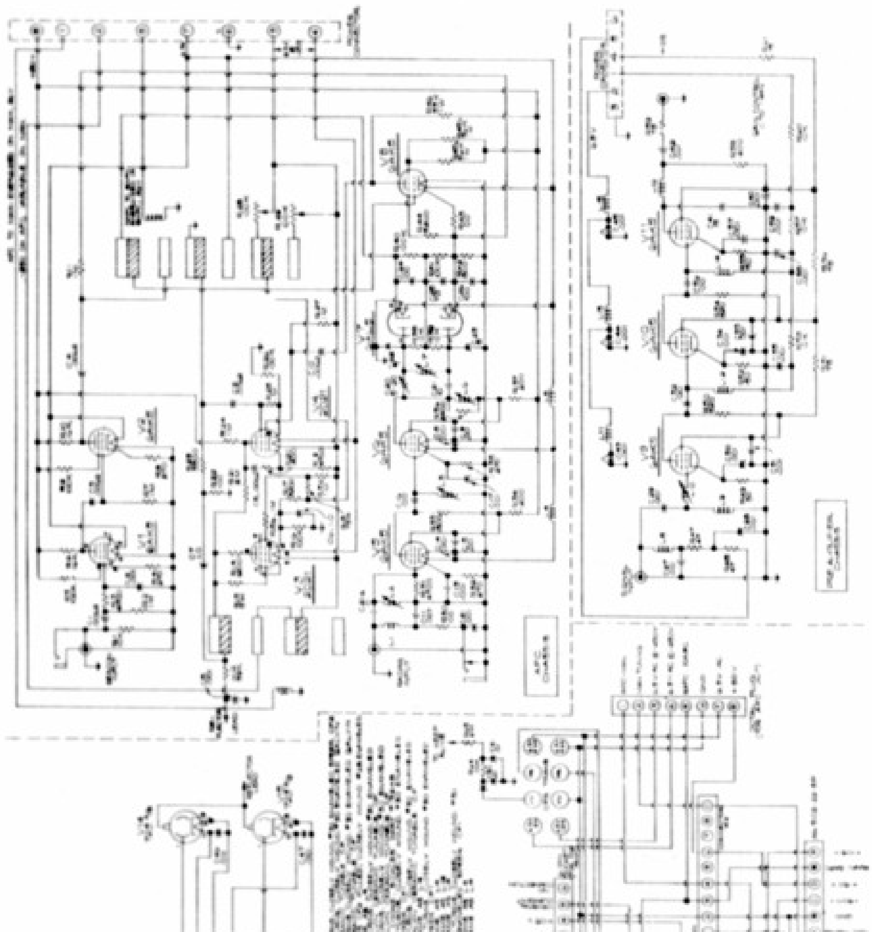


FIGURE 8-4 PRESSURIZED RF UNIT SCHEMATIC DIAGRAM

REEL – C

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ORIGINATING AGENCY: Massachusetts Institute of Technology, Cambridge, Mass.

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ABSTRACT:

Installation, operating, and maintenance instructions are given for an RF unit which is suitable for field modification of existing AN/APS-15A and AP/APS-15 navigation and bombing radar equipment, but the RF unit was designed primarily to improve the beacon reception facilities of the AN/APS-15A. It should also result in more dependable radar operation and reduced maintenance difficulties. An improvement of more than 15 decibels in beacon sensitivity and automatic frequency control for beacon reception has been provided.

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